University of Alberta

"ELECTROMYOGRAPHIC ASSESSMENT OF THE ACTIVITY OF THE MASTICATORY AND CERVICAL MUSCLES USING THE AGONIST CONTRACT – ANTAGONIST RELAX TECHNIQUE (AC)"

by

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Abstract

Proprioceptive neuromuscular facilitation (PNF) techniques are a group of therapeutic procedures that use neurophysiologic principles to stimulate the contraction or relaxation of muscles. Studies have found controversial results when applying these techniques, since there is an increase in the level of electromyographic activity of the muscles instead of a decrease. The aims of the present study were to evaluate the effectiveness of muscle relaxation through the use of two PNF techniques: the agonist contract – antagonist relax (AC) technique and the contract- relax technique (CR). Firstly, the study evaluated the effectiveness of the AC technique in relaxation of masticatory muscles and the cervical muscles. Secondly, the study evaluated whether the AC technique was more effective than the CR technique in causing relaxation in masticatory muscles.

Based on the results obtained from this study, neither technique caused relaxation of the masticatory muscles.

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1. CHAPTER 1: INTRODUCTION

1.1 PROBLEM STATEMENT

Proprioceptive neuromuscular facilitation (PNF) techniques are a group of therapeutic procedures that use neurophysiologic principles to stimulate the contraction (facilitation) or relaxation (inhibition) of particular muscles. One principle of PNF maintains that voluntary muscular contractions are performed in combination with muscular stretching to reduce the reflexive components of muscular contractions, promote muscular relaxation and, subsequently, increase joint range of motion (ROM) (Condon & Hutton, 1987; Etnyre & Abraham, 1986; Ferber, Osternig, & Gravelle, 2002; Moore and Hutton, 1980; Osternig, Robertson, Troxel, & Hansen, 1987).

PNF techniques have been used in rehabilitation medicine and sports medicine for many years to treat muscular problems (Etnyre and Abraham 1986 a, b; Moore and Hutton 1980; Osternig, Robertson, Troxel & Hansen, 1990). Since Kabat introduced these techniques in 1950, based on Sherringtonian principles (reciprocal inhibition, autogenic inhibition), many physiotherapists have used them to improve ROM, to relax and improve the flexibility of muscles, and to diminish the level of muscle activity (Condon and Hutton, 1987; Etnyre and Abraham, 1986b; Guissard, Duchateau, & Hainaut, 1988). However, there are several studies that disagree with these findings. Studies in disagreement have found that inhibitory mechanisms do not satisfactorily explain the results, since there is an increase in the level of electromyographic activity of the muscles instead of a decrease (Condon & Hutton, 1987; Etnyre & Abaham 1986a; Etnyre &Abraham 1986b; Ferber et al., 2002; Moore and Hutton 1980; Osternig et al.,

1987). The majority of studies analyzed focused on the evaluation of the hamstring and soleus muscles (Condon and Hutton 1987; Etnyre & Abraham, 1986; Ferber et al., 2002; Guissard et al., 2001; Handel, Horstmann, Dickhuth, & Gulch, 1997; Mc Hugh, Kremenic, Fox, & Gleim, 1998; Osternig et al., 1987; Osternig et al., 1990), and as a result, information available on this topic is limited and comes primarily from work on the lower limbs.

The craniomandibular system (CMS), as a part of the skeletal system, functions through muscular interaction. Masticatory muscles suffer from the same disorders as the other muscles in the human body and the same neurophysiological principles can be applied. Temporomandibular Disorders (TMD) refer to a group of pathological conditions that affect the temporomandibular joint (TMJ) and masticatory muscles. TMD have been considered as a major cause of non-dental pain in the orofacial region and also as a subclassification of the musculoskeletal disorders (McNeil, 1993). Epidemiological studies performed on specific populations showed that 75% of the population has at least one sign of dysfunction at the TMJ and 33% have at least one symptom (Rugh & Solberg 1985; Schiffmann, 1988). Women are more commonly affected than men by this syndrome, in a ratio 3:1 (Carlsson, 1994). Armijo, Frugone, Armijo & Garcia (2000) obtained an 87% prevalence for a sign or symptom in their analysis of a sample population in Talca – Chile, finding that the most prevalent symptom was pain in the masticatory muscles (57 % of the population). Therefore, it is important to study the best way to treat these disorders to help patients who are affected by this condition.

The aims of the present study were to evaluate the effectiveness of muscle relaxation through the use of two PNF techniques: the agonist contract – antagonist relax

(AC) technique and the contract- relax technique (CR). Firstly, the study evaluated the effectiveness of the AC technique in relaxation of masticatory muscles (the masseter and anterior temporalis) and the cervical muscles (the upper trapezius, and the splenius capitis). Secondly, the study evaluated whether the AC technique (agonist contract-antagonist relax) was more effective than the CR (contract-relax) technique in causing relaxation in masticatory muscles.

1.2 DEFINITION OF TERMS:

Autogenic Inhibition: is a neurophysiologic principle characterized by an inhibition of the same muscle that is contracting as a result of the Golgi tendon organ stimulation or by muscles spindles through type II afferents, which stimulate inhibitory neurons in spinal cord leading to inhibition of the same muscle following contraction (Ganong, 2000).

Agonist contract – antagonist relax technique (AC technique):

The AC technique is a PNF technique characterized by contraction of the agonist muscle of the subject against resistance given by the therapist, and simultaneously, the therapist stretches or relaxes the antagonist muscle. This technique uses the reciprocal inhibition principle, which produces muscular relaxation of the antagonist when the agonist is contracted. This occurs due to afferent impulses from the agonist muscle spindles stimulating the inhibitory neurons in the spinal cord, thereby causing inhibition of the activity in the alpha motoneuron to the antagonist muscle (Leonard, 1998; Stuart, 1996).

Bite Force: This force is determined by the combination of action of masticatory muscles (masseter, temporalis, and pterygoids). This force is measured at the first molar level (greatest force) (Waltimo & Kononen, 1993).

Contract – Relax (CR) Technique:

The CR method is a PNF technique that includes a static stretch, performed by the therapist followed by the subject doing an isometric contraction of the muscle being stretched, and finally, an additional static stretch performed by the therapist. The post - contraction inhibition that results occurs in response to the tension on the Golgi tendon organ from the muscle contraction. This, in turn, causes an autogenic inhibition of the muscle that is contracting (Smith, Hutton, & Eldred, 1974), or stimulation of secondary muscle spindles through type II afferents, which facilitates the stretching of this muscle (Etnyre, Kinugasa, & Abraham, 1990b).

Cervical extensor muscles: These are the muscles that act to rotate the head into extension. They include: the upper trapezius, splenius capitis, semispinalis cervicis, and longissimus capitis, and sternocleidomastoid (if the head is in some extension). At the suboccipital level, the rectus capitis posterior minor, rectus capitis posterior major, obliquus capitis superior, and obliquus capitis inferior extend the cervical spine (Magee, 2000).

Craniomandibular system (CMS): CMS is a system comprised of the head, cervical spine, temporomandibular joint and surrounding tissues such as muscles, fascia, muscles,

nerves and blood vessels. These structures are connected anatomically, physiologically, and biomechanically (Rocabado, 1979).

EMG activity: In this research, EMG activity will be the measurement using an EMG apparatus (BIOPAC Systems®). EMG activity will be normalized with respect to the maximal voluntary referential contraction for each group of muscles (masticatory and cervical muscles). Activity levels will be expressed as percentages of the maximum voluntary reference contraction to give proportional EMG levels. (Burden & Barlett, 1999).

Forward head position: In this research, is defined as chin poking position. The ear is located forward of its normal alignment with the acromion.

Homosynaptic Depression (HD): HD is a progressive decrease in the amplitude of the postsynaptic potential in response to successive presynaptic stimulation. (e.g. when a vibration is applied to a homonymous tendon, this causes a depression of the H reflex). This phenomenon is called postactivation depression. The homosynaptic depression likely is related to a reduced probability of transmitter release (Armitage, & Siegelbaum, 1998).

Hyoid Muscles: The hyoid bone is connected to the cranium, jaw, sternum, and the scapula through the suprahyoid and infrahyoid muscles. The suprahyoid muscles are comprised of the stylohyoid, mylohyoid, genihyoid and digastric muscles .The

infrahyoid muscles consist of the omohyoid (which bridges scapula with the hyoid bone) and the sternohyoid (which connects the sternum and clavicle with the hyoid bone) (Magee, 2000).

Masticatory muscles: These are the muscles that work during the mastication process. They include the superficial masseter, deep masseter, temporalis, external pterygoid, and internal pterygoid (Magee, 2000).

Maximum voluntary referential contraction: This contraction refers to the maximal force registered for:

a. Masticatory muscles: maximal isometric force when the subject is biting against a bite load cell located in the first molar zone.

b. Cervical muscles: maximal isometric force registered by a load cell when the subject's head is pushing backward in the supine position.

Neurophysiological principles: These principles are based on the neuronal connection and nervous pathways that inhibit or facilitate the pools of neurons to cause relaxation or stimulation of the muscles. These principles were described by Sherrington. They include reciprocal inhibition, autogenic inhibition, and facilitation (Kandel & Shwarz, 2000).

Proprioceptive Neuromuscular facilitation techniques (PNF): PNF techniques are a group of techniques such as the contract – relax technique (CR), the agonist contract – antagonist relax technique (AC), and the contract –relax-agonist-contract technique (CRAC) that are used to improve the range of motion of a joint by increasing the

flexibility of the muscles, based on neurophysiological principles such as reciprocal inhibition and autogenic inhibition (Osternig et al. 1987).

Reciprocal inhibition: neurophysiological principle that produces muscular relaxation of the antagonist when the agonist is contracted. Afferent impulses from the agonist muscle spindles stimulate an inhibitory neuron in the spinal cord, causing inhibition of the activity in the alpha motoneuron of the antagonist muscle (Stuart, 1996).

Standardized Head Posture: the posture of the subject when his/her visual axis is horizontal (Cooke, 1988).

Stomatognathic system: The stomatognathic system is an integrated and coordinated morphofunctional unit, consisting of skeletal, muscular, circulatory, nervous, glandular and dental structures, organized around the occipitoatlanto, atlanto-axial, cervical, temporomandibular, and dento-alveolar joints. This system works functionally with the digestive, respiratory, and articulatory systems, and esthetic-facial expression. It also works in concert with the senses of the taste, touch. Suction functions, oral digestion (which includes mastication, salivation, tasting and the initial degradation of carbohydrates); swallowing; verbal communication (involves, among other actions, speech, whistle and desire); oral sexuality (includes a smile, laugh, bucofacial gesticulation, a kiss, among other aesthetic-affective manifestations); alternating breathing and vital mechanisms of defense, integrated by a cough, expectoration, sneeze,

yawn, sigh, exhalation and vomit, essential for the survival of individual are also part of this system (Barreto, 1999).

Temporomandibular Disorders (TMD). TMD are also called craniomandibular disorders (CMD). These disorders are a group of pathologies that affect the craniomandibular system. Their definition is complex because there is no agreement about which signs and symptoms are necessary to describe this condition (De Wijer, Steenks , Bosman, Helders ,& Faber ,1996). However, according to some authors, craniomandibular disorders are characterized by pain in the joints and /or jaw muscles, clicking or sounds in the temporomandibular joint (TMJ) and alterations in mobility of the jaw (these 3 signs are called cardinal points). Some authors include alterations in the craniocervical system because researchers have found that problems related to the cervical spine exist in patients with TMD (Clark, Green, Dornan, & Flack 1987; De Wijer et al. 1996; Friedman M.H. & Weisberg 1982; Lobezzo- Scholte, Steenks, & Bosman, 1993). This evidence demonstrates that the cervical spine and craniocervical system are related to the masticatory system since they work as a functional system and they should be considered together to evaluate and treat patients who suffer from TMD.

1.3 OBJECTIVES OF THE STUDY:

The objectives of this study were as follows:

1. To evaluate the effectiveness of the agonist contract – antagonist relax technique (AC) in relaxation of the masseter, anterior temporalis and cervical muscles (the upper trapezius, and splenius capitis) through electromyographic activity assessment.

2. To demonstrate that the AC technique will lead to greater relaxation than the contract-relax technique (CR) when exercising the masticatory muscles (masseter and anterior temporalis).

The cervical muscles (the upper trapezius, splenius capitis) were selected according to biomechanical and practical criteria. The lever at the craniocervical level is a first order lever, which implies that if there is movement in the mouth or cervical spine in the sagittal plane, the muscles that must be analyzed are the muscles that control the movement in this plane. In this research, the movement to be analyzed is mouth opening against resistance, which causes a flexion moment in the cervical spine. This movement is controlled by the cervical extensor muscles that are located closer to the center of rotation in the frontal plane to maintain the equilibrium of the craniocervical system and to prevent the head from dropping anteriorly. The upper trapezius and splenius capitis are localized closer to the point of rotation of the cervical spine in the frontal plane. Therefore, it is thought that they work best to control head and cervical movement in the sagittal plane (flexion and extension).

In summary, the selection of the neck muscles (upper trapezius, splenius capitis) for this investigation was determined by the following criteria:

a. The possibility of recording the electromyographic activity of these muscles (EMG) using surface electrodes.

b. Their function as extensors of the cervical spine

c. Their anatomic location (closer to the axis of movement).

1.4 RESEARCH HYPOTHESES:

The following hypotheses were investigated in this study:

1. The AC technique (when it is applied to the suprahyoid and infrahyoid muscles) will cause a decrease in electromyographic activity in the masseter, anterior temporalis, upper trapezius, and splenius capitis muscles.

2. The AC technique will cause greater relaxation of the masticatory muscles (the masseter, anterior temporalis), causing a greater decrease in EMG compared with the CR technique after each technique (the AC and the CR).

1.5 LIMITATIONS OF THE STUDY:

This study was limited by:

1. The reliability of EMG machine.
2. The reliability of the bite force tool

3. The ability of the researcher to apply the same procedure for every subject. This factor was controlled by the evaluator making sure that the same procedure was used for every subject:

    3.1 Electrode placement: The references for placement of electrodes were the same for every subject following anatomical landmarks.

    3.2 The instrumentation and location used for testing were the same for all subjects.

    3.3 The same evaluator assessed all subjects.

    3.4 The instructions were the same for every subject.

4. The ability of the researcher to determine which patients have TMD. The TMD diagnosis was performed based on the following criteria:

    4.1 Pain in the TMJ and masticatory muscles

    4.2 Sounds in the TMJ

    4.3 Limitation of range of motion in TMJ (< 30 mm)

5 Potential researcher bias when reading and analyzing the results (even if the measurements were concrete). The sources of bias could be the potential error when analyzing the EMG signal and calculating the RMS in a period of time since the evaluator had to choose a signal period to analyze. These biases were limited as much as possible by the following:

    5.1 All the signals were obtained using the same procedure for all subjects.

5.2 All analyses followed a standardized procedure: all were collected using the same frequency, and were filtered using the same kind of filters.

5.3 All calculations were performed by the same software program, using the same instructions.

5.4 The period of time used for each analysis was the same, (5 seconds before, 10 seconds during and 10 seconds after applying the AC or CR technique).

6. This research will be applicable only in the following conditions:

6.1. Normal subjects

6.2. Under the same conditions and procedures.

6.3. Only for the muscles described and analyzed.

1.6 DELIMITATIONS OF THE STUDY:

This study was delimited to:

1. Test subjects having normal craniomandibular systems with no known pathology
2. Subjects examined were between 18 and 35 years old and of both sexes.
3. This study dealt only with the AC technique (the agonist contract-antagonist relax technique) and CR (the contract-relax technique).

1.7 ETHICAL CONSIDERATIONS

This research was performed while maintaining total privacy of the subjects. The benefit of this research was to provide a better basis to the physiotherapist's knowledge of future treatment for patients who suffer muscular problems in the craniomandibular system. All of the procedures were non-invasive, the only potential risk was dental fracture during maximal clench in a restored tooth during the testing (Ferrario, Sforza, Serrao, Dellavia, & Tartaglia, 2004; St-Georges, Sturdevant, Swift Jr., & Thompson 2003). This possibility was minimized since subjects were evaluated by a dentist before doing the testing to ensure that the subjects had a decreased chance of a dental fracture. During the procedure, no subject suffered a dental fracture.

Consent from the Ethics Committee of The University of Alberta and informed consent (Appendix 1-2) from the subjects were obtained before the individuals were enrolled in this study.

CHAPTER 2: LITERATURE REVIEW

2.1 METHODS AND MECHANISMS OF PNF TECHNIQUES

Proprioceptive Neuromuscular Facilitation (PNF) was introduced by Kabat in 1950 and was later developed by Knott and Voss (Etnyre et al., 1986). Several major techniques have been used in stretching programs such as contract – relax (CR), agonist contract – antagonist relax (AC) and contract-relax – antagonist-contract (CRAC) under the general term Proprioceptive Neuromuscular Facilitation.

The CR method includes a static stretch performed by the therapist, followed by isometric contraction of the muscle being stretched by the subject, and finally an additional static stretch performed by the therapist. The post - contraction inhibition apparently results in response to the tension on the Golgi tendon organ from muscle contraction. This causes an autogenic inhibition of the muscle that is being contracted, (Smith at al., 1974) or on the muscles spindles through type II afferents, which facilitates the stretching of this muscle (Etnyre et al., 1990b).

The AC technique is characterized by contraction of the agonist muscle against a resistance provided by the therapist simultaneously stretching and relaxing, the antagonist muscle. This technique uses the reciprocal inhibition principle, which produces muscular relaxation of the antagonist when the agonist is contracted. This is thought to be due to afferent impulses from agonist muscle spindles stimulating an inhibitory neuron in the spinal cord, causing inhibition of the activity in the alpha motoneuron to the antagonist muscle (Leonard 1998; Stuart, 1996).

Another technique is CRAC, which is similar to CR, the difference being that the antagonist muscle is contracted in the final stretch. This technique sequence is as follows: the muscle being stretched is passively put in the stretch position by the therapist; the patient then isometrically contracts the stretched muscle against resistance given by the therapist. Finally, the patient isometrically contracts the antagonist or opposing muscle, using the reciprocal inhibition principle as well.

2.2 NEUROPHYSIOLOGIC PRINCIPLES OF PNF

Every PNF technique is based on neurophysiological principles. These principles are known as Sherringtonian principles because Sherrington was the first to describe them. The main principles are autogenic inhibition and reciprocal inhibition, both of which are very complex in that there are many mechanisms involved in each.

2.2.1 MONOSYNAPTIC REFLEX:

The monosynaptic reflex is one of the most primitive reflexes in humans. It is present even in lowly intervertebrates. The monosynaptic reflex has only one synapse involved in its pathway. One of the classic monosynaptic reflexes is the stretch reflex, which is a good example of the relationship that exists between sensory input and motor output (Leonard, 1998). This reflex is elicited when a clinician taps a tendon. Stretching a muscle activates muscle spindles and causes the stretched muscle to contract. The muscle spindles (stretch receptors) send the information via Ia afferent fibers directly to the motoneurons, which begin in the spinal cord, and innervate the stretched muscle, causing

its contraction. Only two neurons are necessary to obtain this response. One is a sensory neuron in the dorsal root ganglion and the other is a motor neuron in the ventral horn of the spinal cord. The Ia afferent fiber conveys the sensory information from the stretched muscle and tends to branch and carry its message, ascending to higher brain centers with information on changes in peripheral conditions; or others can synapse at various interneurons, and still others will synapse at motoneurons of synergist muscles, which assist with the task. Most tasks require multiple muscular actions to allow a coordinated movement. Much of the coordination and activation of muscles across several joints is provided by propriospinal neurons. Propriospinal neurons are interneurons that cover multiple spinal cord segments. They have a range of action more developed than that of the remaining neurons. Propriospinal interneurons send information to interneurons and motor neurons located several spinal segments away from their cell bodies. These connections allow for the coordinated movement involved in postural adjustment and voluntary movement (Leonard, 1998).

Evars (1973) supports the idea that the monosynaptic reflex could be influenced by superior centers. If this is the case, the responses at spinal level are modulated by some brain areas, and the components of the human reflex can change as a result of lesions in the brain.

2.2.2 DISYNAPTIC Ia INHIBITORY INTERNEURON: RECIPROCAL INHIBITION

Human movement requires not only muscular activation but also muscle deactivation. To carry out many complex tasks, human beings need to have a system that

controls or modulates muscle actions. Reciprocal inhibition is the neurophysiological principle under which this process can be explained.

When the stretch reflex is elicited, impulses travel through type Ia afferent fibers which connect with a type of interneuron in the spinal cord called Ia inhibitory interneuron .This interneuron secretes a neurotransmitter (Glycine) that has an inhibitory effect on motoneurons innervating antagonist muscles to the stretched muscles . This process is also called "disynaptic inhibition" because there are two synapses involved in the inhibitory process. The Ia inhibitory interneuron receives information not only from Ia afferent fibers, but also from other centers. It is a center of convergence of information. The Ia interneuron processes this information and controls the precise amount of inhibition that is necessary to achieve coordinated and perfect movement. Reciprocal inhibition is not the only way that the nervous system (NS) can cause inhibition. There are other mechanisms such as Renshaw cell mediated inhibition, Ib fiber mediated inhibition, and a presynaptic inhibitory mechanism. These mechanisms, together with descending pathways, can grade the strength of contractions based on particular situations (Leonard, 1998; Ganong, 2001).

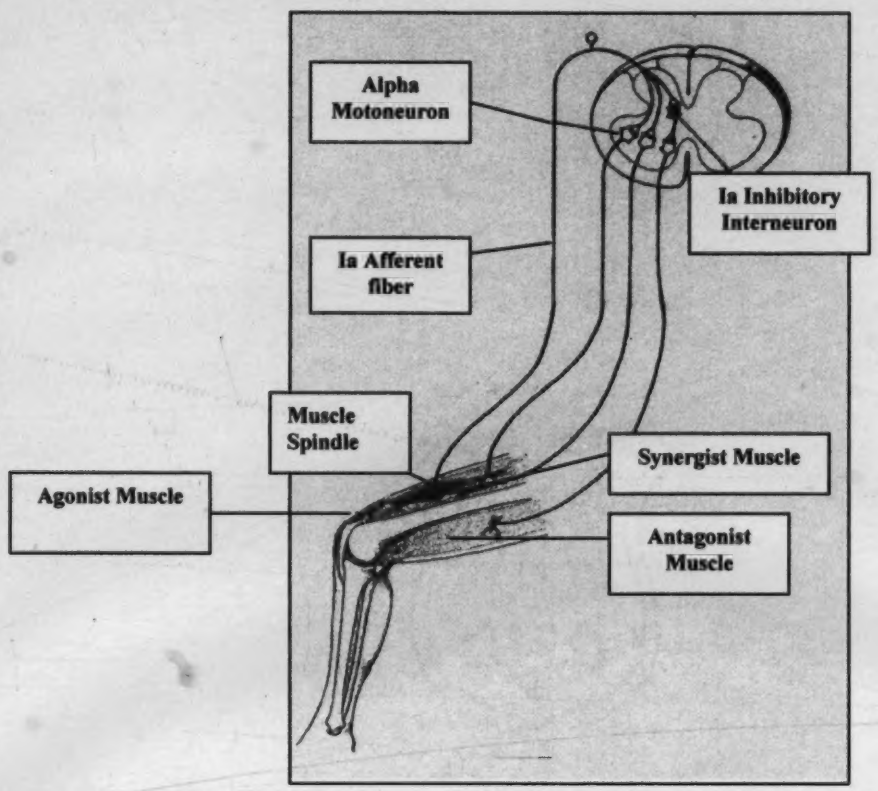


Figure 1: Reciprocal inhibition.

Reciprocal Ia inhibition is considered to be one of the most important neural mechanisms in the development of movements. This mechanism has been extensively investigated in animals. It has also been studied in the human beings, principally in the leg muscles.

Sinkjaer, Nielsen & Toft (1995) studied the effect of reciprocal inhibition in the stretch reflex when the neural activity of afferent fibers in the common peroneal nerve (CPN) was blocked by lidocaine in the ankle plantar flexors. They found that the reflex mediated mechanical effect around the ankle was abolished. This observation

demonstrated that important reciprocal inhibition pathways are controlled by descending neural control signals. The pathways that mediate the reciprocal inhibition are often to be assumed highly dependent on fusimotor activity through the Ia afferent activity of the antagonist muscles. However, other authors have argued that the soleus H reflex was inhibited 20-50 ms before the start of the EMG activity of the tibialis anterior (TA). This evidence demonstrated that inhibition was initiated by supraspinal structures, because human Ia afferents were not activated until 20- 40ms after the onset of voluntary EMG activity (Valbo, 1970). On the other hand, Sinkjaer et al. (1995) demonstrated in the same study that the stiffness of the ankle joint could be influenced by reciprocal inhibition, because the block of the CPN caused an increase in stiffness of this joint.

Studies performed by Kasai & Komiyama (1988) evaluated the effect of phasic dorsiflexion movement on the excitability of the motoneurons in the tibialis anterior and soleus muscles. They found that initiation of agonist facilitation and antagonist inhibition might simultaneously start before TA EMG onset. This result demonstrated that agonist and antagonist motoneurones simultaneously received subliminal facilitation via type Ia inhibitory interneurons and inhibition from the brain before EMG onset. They also found that the level of contraction (10% or 50% MVC) did not modify the onset time.

Crone and Nielsen (1994) performed research in which they blocked the common peroneal nerve through the injection of a local anesthetic (lidocaine). They found that when the subject attempted to dorsiflex the ankle, without movement, a strong depression of the soleus H reflex was seen. This finding demonstrated that the brain was able to inhibit the soleus motoneuron pool in the absence of a peripheral input from the ankle

dorsiflexors. They concluded, based on a review of the literature, that disynaptic reciprocal inhibition was under central control.

Shindo, Harayama, Kondo, Yanagisawa, & Tanaka (1984) found that the Ia inhibitory pathway from the ankle flexor to the extensor was facilitated during tonic voluntary dorsiflexion and was depressed during voluntary plantar flexion. The absolute amount of the Ia inhibition in ankle extensors increased almost in parallel with the amount of contraction exerted by the ankle flexors at 10%, 20%, and 30%.

2.2.3 RENSHAW CELL- MEDIATED RECURRENT INHIBITION

Renshaw interneurons directly synapse on alpha motoneurons and Ia inhibitory interneurons. They also receive convergent input from multiple descending and segmental inputs, but their principal input is from the alfa motoneuron. The collateral from the alfa motoneuron to the Renshaw cell is called the recurrent collateral, hence the name "recurrent inhibition". The alpha motoneuron that activates the contraction of the muscle will also activate its Renshaw cell, which will synapse back to the alpha motoneuron and inhibit it and its synergist via collateral action. Therefore, any activation of the Renshaw cell, from its alpha motoneuron or other sources will decrease motor neuron output (Stuart, 1996). However, many questions remain concerning this mechanism because there is no explanation as to why these cells cause an inhibition of their own stimulated motoneuron. Renshaw neurons also inhibit the gamma motoneurons of the muscles that the motoneuron stimulates, and, in addition, inhibit antagonist muscle Ia inhibitory interneurons. In conclusion, Renshaw neurons are a variable regulator. They

inhibit their agonist muscle and disinhibit their antagonist muscle through Ia inhibitory interneuron connections (Leonard, 1998).

Renshaw cells are under central control from descending brain stem and cortical pathways. The relative output from these cells is regulated by descending systems which may enable the Renshaw neurons to modify the relative excitation or inhibition of multiple muscles during a particular movement (Leonard, 1998; Stuart, 1996).

When a movement occurs, synergist muscles, for example, receive information through the Ia afferent from the principal muscle, which will cause excitation of these muscles. However, postsynaptic excitatory effects of these muscles by Ia afferent input will be counterbalanced by the Renshaw neuron, causing recurrent inhibition of the first mover muscle .Therefore, synergist muscles receive weaker information from the Ia afferent fibers than the first mover muscle, and they are more affected by Renshaw cell inhibition. This is a form of gradation of the contractions (Stuart, 1996).

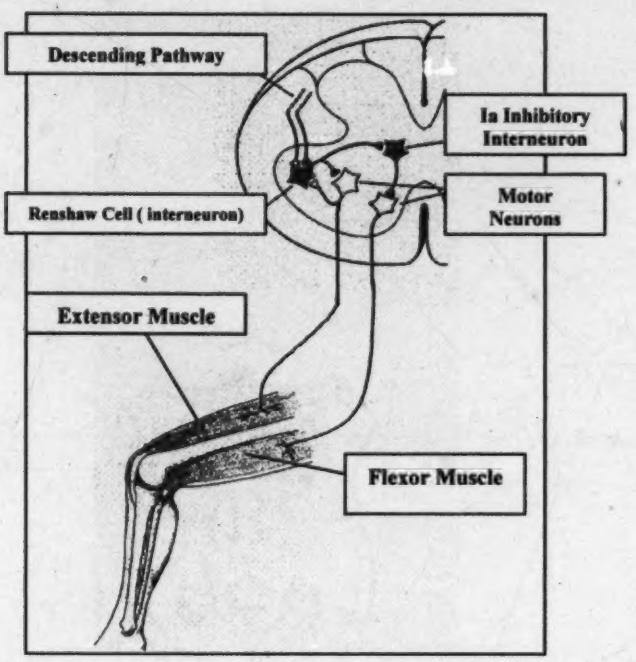


Figure 2: Renshaw recurrent inhibition.

2.2.4 AUTOGENIC INHIBITION

Autogenic inhibition is another mechanism that works to regulate muscular activity. The Golgi tendon organ (GTO) detects changes in muscle tension. This information is carried via Ib afferent fibers that synapse on Ib interneurons. Increased activity in the Ib interneuron causes inhibition of the motoneuron of the muscle that generated the initial muscle force. The more tension that is generated by a muscle, the more active the Ib inhibition back to its motoneuron is. The Ib interneuron receives information not only of the GTO, but also from Ia afferent fibers and the joint, as well as cutaneous afferents, and it is also under the central control through the corticospinal tract,

rubrospinal tract, and the lateral reticulospinal tract (Ganong 2001; Leonard, 1998; Stuart, 1996).

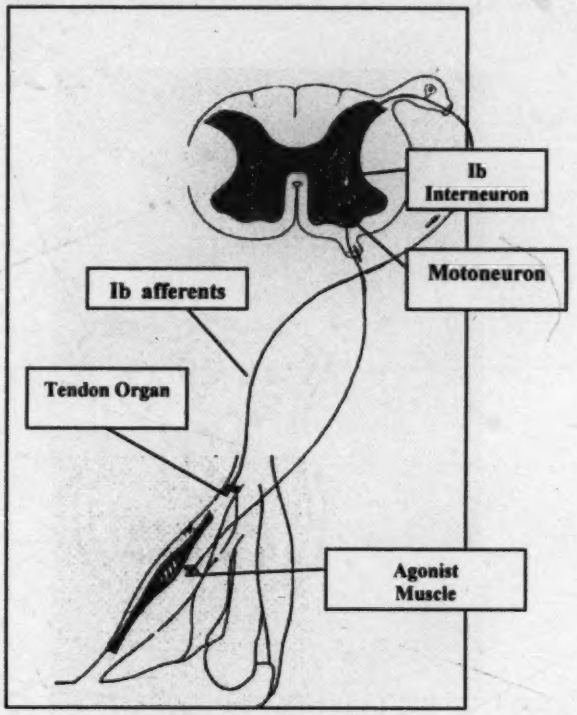


Figure 3: Autogenic inhibition.

2.2.5 MODULATION OF REFLEX ACTIVITY

2.2.5.1 PRESYNAPTIC INHIBITION: This phenomenon causes inhibition along a neural pathway by decreasing the amount of neurotransmitter released by the neuronal axon before it synapses with another neuron. The amount of excitatory neurotransmitter released at the end of an axon is regulated by a second neuron, which synapses with the first neuron, causing a decrease in the neurotransmitter release (Stuart, 1996 b). This decreases its effect on the postsynaptic neuron. Presynaptic inhibition works by limiting the amount of transmitter released by the presynaptic axon terminal.

Several mechanisms may be involved in this process. First, the activation of presynaptic receptors increases chloride (CL^-) conductance which decreases the size of the action potentials reaching the excitatory ending, diminishing the amount of neutransmiter released. Another mechanism may be the opening of voltage –gated potassium (K+) channels, and as a result of potassium efflux, the Calcium (Ca^{++}) influx is decreased. Finally, there is evidence that direct inhibition of transmitter release independent of Ca^{++} exists in the excitatory endings (Ganong, 2000). Gamma-amminobutyric acid (GABA) neurotransmitter is the first transmitter known to cause presynaptic inhibition, but there are others. GABA causes increases CL^- conductance, acting through GABA receptors.

2.2.5.2 POSTSYNAPTIC INHIBITION: This process causes hyperpolarization of the postsynaptic membrane (Leonard, 1998). Afferents fibers from the muscle spindles in skeletal muscle pass directly to the spinal motor neurons from the same muscle. Impulses in this afferent cause excitatory post-synaptic potentials (EPSP), propagating a response in postsynaptic motoneurons. At the same time, inhibitory postsynaptic potentials are produced in motoneurons from the antagonistic muscles. This response is mediated by branches of the afferent fibers that end in the GTO. These neurons secrete an inhibitory transmitter , called Glycine, which inhibits the antagonist muscles through synapses with proximal dendrites or cell bodies of the antagonist's muscle (reciprocal innervation) (Ganong, 2001).

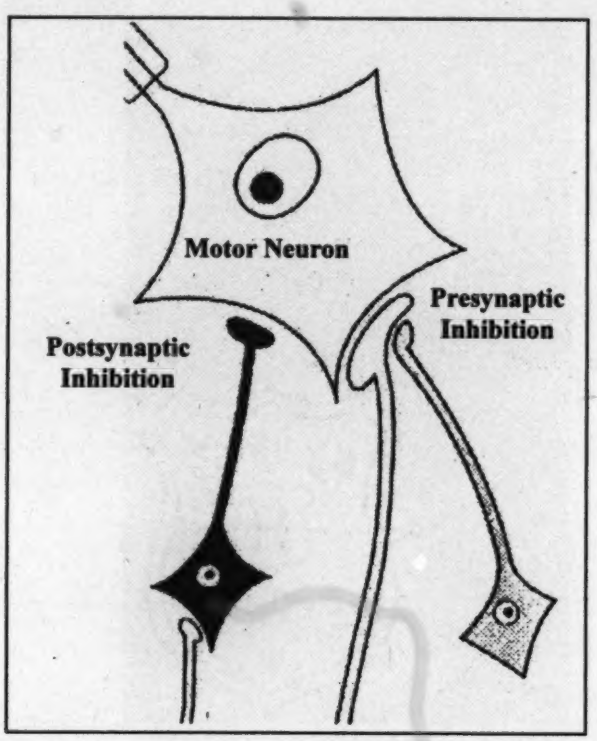


Figure 4: Presynaptic and postsynaptic inhibition.

2.3 EFFECTIVENESS OF PNF TECHNIQUES: COMPARISONS

Since Sherrington in 1900 defined the basic concepts of muscle facilitation and inhibition, these concepts have been the basis for PNF techniques. These concepts are used to increase ROM and decrease the resistance of the muscles by muscular relaxation. Although PNF stretching techniques are believed to reduce reflexive components that stimulate muscular contraction, few studies have provided neurophysiologic evidence of the effectiveness of PNF stretching techniques. Previous investigations have also shown that while PNF techniques achieve a gain in ROM, electromyographic (EMG) activity in the muscle being stretched is not necessarily reduced, and in some cases, is actually

increased (Ferber et al., 2002; Moore & Hutton, 1980; Osternig et al,. 1990). These studies suggest a paradoxical ROM/ muscle tension relationship in that PNF stretching may not induce muscular relaxation even though the ROM about a joint increases. According to the literature, there is some controversy related to the effectiveness of the PNF techniques. Some authors are in agreement with their benefits (Carter, Kinzey, Chitwood, & Cole, 2000; Condon & Hutton, 1987; Etnyre et al., 1986; Etnyre & Abraham, 1986; Etnyre & Lee, 1988; Ferber et al., 2002; Godges, Mattson-Bell, Thorpe, Shan, 2003; Lucas and Koslow, 1984; Osternig et al., 1990; Osternig et al. 1987); however, others have obtained results that show no benefit (Condon & Hutton, 1987; Etnyre et al., 1986; Etnyre & Abraham, 1986; Etnyre & Lee, 1988; Ferber et al., 2002; Osternig et al., 1990; Osternig et al., 1987).

The effectiveness of the CR technique is based on autogenic inhibition. This means that this technique causes muscular relaxation after a muscular contraction provided by GTO action and stimulation of the inhibitory neurons in the spinal cord. Gollhofer, Schopp, Rapp, & Stroinink (1998), who studied the response in reflex excitability (H reflex) after isometric contraction at 30% and 60% of the maximal voluntary contraction (MVC), argued that the CR technique produced marked reduction in reflex excitability, with no difference between the level of contraction. However, this effect had a very fast recovery (<400ms). This idea contradicts the principle that the isometric pre-contraction might be used for more efficient stretching of the muscular system since there is a quick recovery after mechanical stretching.

Passive stretching of the triceps surae has been associated with decreased Hoffmann (H) reflex amplitude in the soleus only during the first few seconds after the

beginning of the stretch, which demonstrates that there probably is a small time at the beginning of the stretching when the muscle decreases its activity (Condon & Hutton, 1987; Etnyre & Abraham, 1986b).

PNF techniques, especially those involving reciprocal inhibition ,such as the AC and the CRAC, do provide the greatest potential for muscle lengthening (Etnyre and Abraham1986a,1986b; Guissard et al.,1988), due to increased suppression of the motor pool, which is manifest by early post contraction latencies (Etnyre & Abraham,1986b). Probably the greater effectiveness of the CRAC and AC stretching exercises is the result of the marked and lasting suppression of motor pool excitability (Etnyre & Abraham, 1986b). These findings are in agreement with studies of reciprocal inhibition performed by Kasai and Komiyama (1991) and Leonard, Sandholdt, & McMillan (1999) in the lower extremities. However, according to other authors (Osternig et al.,1987), these techniques (the AC and the CRAC) do not produce sufficient muscular relaxation but rather increased muscle vulnerability to soreness and strain if stretching is continued due to the increased muscle level of activity. They also found that although the static stretching (SR) technique caused less ROM than the others (the CR and the CRAC), it caused the greatest reduction in muscle activity and for this reason, may be the safer stretching technique. These findings show that PNF techniques improved the ROM by decreasing the motor neuronal excitability of the muscles being stretched, but they also caused an increase in EMG activity.

Passive stretching, preceded by a maximum voluntary isometric contraction of the stretched muscle (the hold-relax method) or assisted by the contraction of its antagonist (the antagonist contract method), induced greater joint flexibility than static stretching

(SS) and greater H -reflex inhibition when compared to passive stretching technique alone (Guissard et al,1988). The inhibition caused by the CR and AC techniques lasted at least 25 seconds. This observation is very important for clinical practice because stretching must be maintained for at least this much time to take advantage of the inhibition caused by these techniques (Guissard et.al 1988).

Determining the mechanism that mediates changes in reflex activity during stretching techniques remains an interesting pursuit because several possibilities should be considered at pre-and post-synaptic sites. Neural adaptations can contribute to greater muscle flexibility during stretching. The neural theory of flexibility however has not been substantiated (Mc Hugh et al., 1998). Presynaptic changes that could explain a drop in H reflex response during stretching are the following: an autogenic decrease in Ia afferents induced by presynaptic inhibition, an altered capacity for synaptic transmission during repetitive activation, and homosynaptic depression (Guissard, Duchateau, & Hainaut, 2001).

On the postsynaptic side, the following processes could also explain a decreased H reflex during stretching. Autogenic inhibition is induced by the Golgi tendon organ afferents which send information through Ib fibers to control muscular tension and to allow relaxation of the muscle. Secondly, the recurrent inhibition via the Renshaw loop, activated by descending commands, could decrease the motoneurons activity and postsynaptic inhibition as a result of afferents from joint and cutaneous receptors. Third, supraspinal afferents could also play a role in the modulation of the spinal reflex pathway during stretching (Sinjjaer et al 1995).

2.4 THE CRANIOMANDIBULAR SYSTEM AND THE TEMPOROMANDIBULAR DISORDERS

2.4.1. CRANIOCERVICAL RELATIONSHIPS

The cranium is connected to the cervical spine through the occipitoatlanto joint. The occipital condyles articulate with the lateral masses of the atlas, which are part of the superior cervical spine. In addition, the cranium is connected to the jaw through the temporomandibular joints between the temporal bone of the cranium and the mandible. All of these structures are joined by the capsuloligamentous, muscular, vascular, lymphatic, and nervous systems that maintain normal activity.

The mandible is controlled by the masticatory muscles and is a bridge to the scapula through the hyoid bone. This relationship is an important and complex biomechanical one since all these structures have an interrelated function and their pathological problems can be connected as well (Rocabado, 1979).

The hyoid bone is connected to the cranium, jaw, sternum, and scapula through the suprahyoid and infrahyoid muscles. The suprahyoid muscles include the stylohyoid, mylohyoid, geniohyoid and digastric muscles, while the infrahyoid muscles consist of the omohyoid (which bridges the scapula with the hyoid bone) and the sternohyoid (which connects the sternum and the clavicle with the hyoid bone).

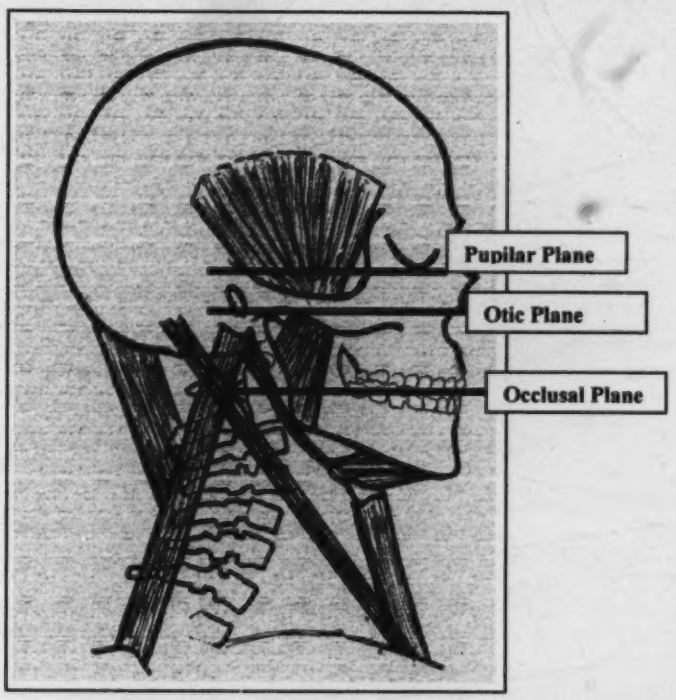


Figure 5: Craniocervical system: anatomic view and craniocervical stability. occlusal, otic, and pupilar planes have to be parallel in space.

Craniocervical posture achieves equilibrium and stability when the eyes are in a horizontal position and the masticatory and auriculonasal plane are parallel with each other and horizontally located (see Figure 5) (Rocabado, 1979). The postural stability of the head and cervical spine is regulated by the action of the mechanoreceptors of the upper cervical spine and the receptors of the temporomandibular joint. This nervous regulation works in conjunction with the muscular action of the posterior cervical muscles that maintain the head in the horizontal position (Kapandji, 1990).

Many factors control craniocervical posture, including the vestibular and visual apparatus, the proprioceptors of the neck, the hyoid position, and muscular activity.

Muscular activity involves the small muscles in the craniocervical and cervical spine, including the rectus capitis posterior major and minor, obliquus capitis superior, obliquus capitis inferior, and multifidus. In addition, large muscles such as trapezius, splenius capitis, and semispinalis capitis work with the small muscles to maintain equilibrium (Panjabi, 1990).

To understand the mechanisms that are necessary for maintaining equilibrium and stability of the cranium and cervical spine, it is necessary to understand the mechanical function of this complex system.

At the level of craniocervical joints, the lever is a first degree or order lever with the rotation point or fulcrum located in the occipitoatlanto joint. Resistance is provided by the weight of the head where the center of gravity is located anteriorly. Power for movement and stabilization is provided by the posterior cervical muscles (e.g. the trapezius, splenius, semispinalis, and multifidus), which have to work constantly to maintain the stability and the position of the head, as it has a tendency to "drop" anteriorly when in an upright posture (Kapandji, 1990; Rocabado, 1979).

The relationship among the cranium, cervical spine and stomatognathic system has been studied by many researchers (Kohno S, Kohno T, Medina, 2001a; Kohno, Matsuyama, Medina, & Arai, 2001 b; Mckay et al 1999; Mohl, 1976; Preiskel, 1965; Okeson, 1998; Rocabado, 1984; Torisu, 2001; Visscher, 2000; Yamada, 1999). Some researchers have shown that cervical and craniocervical posture are related to the position of the mandible and facial structures and any intervention or modification in the craniocervical system could have an effect on the stomatognathic system and vice versa (Kohno et al 2001; Mckay & Christensen, 1999; Mohl, 1976; Moya & Miralles 1994;

Torisu,Yamabe, Hashimoto, Yoshimatsu & Fuji, 2001; Vischer, Huddleston, Lobbezoo & Naeije, 2000). For instance, Moya & Miralles (1994) stated that when patients were treated with occlusal splints for sternocleidomastoid and trapezius spasms, the increase in the vertical occlusal dimension that occurred generated significant craniocervical extension and a decrease in the cervical spine lordosis. This observation can be explained by the fact that when the mouth opens, the head rotates backward (Kohno et al., 2001; Mohl, 1976; Okeson, 1998; Preiskel, 1965; Yamada et al., 1999) and this movement causes a decrease in the cervical lordosis, since the cervical spine tends to move in the opposite direction in relation to head movement. On the other hand, Solow & Tallgren (1976) determined that the extension of the head on the cervical spine was associated with a significant mandibular retrusion. This has been reported to be the result of the stretching of the soft tissues that attach to the jaw (Okeson, 1998), the tension of the inframandibular tissues (Preiskel, 1965) or to the gravity force (Vischer et al., 2000).

An abnormal craniocervical posture, such as the forward position of the head (chin poking position), has been related to craniomandibular disorders (A.De Wijer et al., 1996; Rocabado, 1984). Braun (1991) examined craniomandibular (CMD) patients who also complained of neck pain and concluded that these patients showed a more forward position of the head than healthy controls.

2.4.2 TEMPOROMANDIBULAR DISORDERS:

2.4.2.1 EPIDEMIOLOGY

Epidemiology has been defined as the study of the distribution, determinants, and natural history of disease in populations (Lilienfeld, A. & Lilienfeld, D., 1980). This science helps to understand the disease process determining those factors most valid for determining the correct diagnosis. Generally, the epidemiologic criterion to evaluate prevalence is based on the cardinal points of TMD, which were mentioned previously (see page 9). According to the cardinal points, and based on the information from epidemiologic studies, it was assumed that 75% of the patients evaluated in one study performed by Rugh and Solberg (1985) exhibited at least one sign such as joint noise or palpation tenderness and 33 percent of the non-patient population showed at least a symptom that would potentially lead the subject to seek evaluation and care. These results are in agreement with the results found by Armijo et al., (2000), who obtained a 87% prevalence for a sign or symptom for TMD in their analysis of a sample population in Talca, Chile. They found that the most prevalent symptom was pain in the masticatory muscles (57 % of the population).

Signs and symptoms of TMD in the general population have been found to occur only slightly more frequently in females than in males. However, other studies revealed that the ratio between females and males to be approximately 2:1 (Agerberg & Carlsson, 1972; Glass, McGlynn, & Glaros, 1993; Heft, 1984; Schiffman& Fricton 1988) or 3:1 (Carlson, 1994).

The most common sign of TMD is temporomandibular clicking and occurs in about 50% of the TMD population. Clicking sounds may indicate local irregularities of the articulating components with or without internal derangement of displaced disc. According to a study performed by Ribeiro et al., (1997), 86 % of the patients with TMD had displacement of the disc shown on magnetic resonance imaging. However, displacement of the disc does not necessarily result in a symptomatic joint and clicking may not progress to locking and joint degeneration (De Leeuw, Boering, Stegenga & De Bont , 1994; Nikerson & Boring , 1989).

Related to the associated symptoms of TMD, cervical symptoms, such as neck pain have been found in approximately 75% of the TMD patients. Moreover, 72 % of these patients reported pain in other areas of the head and the masticatory region, and 72 % reported back pain (Garro, Stephenson & Good, 1994).

2.4.2.2. ETIOLOGY

The etiology of the TMD has been studied for many years .There are many theories that try to explain the mechanisms that cause TMD. Occlusal disharmony, malocclusion, malposition or malformation of the condyle, abnormal form and position of the fossa , previous trauma , orthodontic treatment , bruxism, stress, muscle parafunction, hard diet, oral posture, sleep disorders and poor head posture have been considered as part of multiple theories related to the TMD. Every theory tries to explain the TMD etiology, providing some statement about each factor. For instance, people who have sleep disorders and people who clench or brux have greater possibility of having

TMD (Mew, 1997). Another example is the theory that states that malocclusion precipitates TMD (Mew, 1997). However, these theories do not cover all the possible explanations about TMD sources since some patients exhibiting factors such as malocclusion (increased overjet, lateral open bite), bruxism, or patients who have sleep disorders do not experience signs and symptoms of TMD. Whether a factor will cause TMD or not in a patient will depend on the patient's characteristics and the balance of her/his craniomandibular system (Mew, 1997).

In the craniomandibular system, there is normally a balance between all structures involved in the functioning of this system including teeth, masticatory and cervical muscles, and temporomandibular joints structures, as well as the psyche of the individual. This balance can be disrupted by a number of factors such as functional factors, structural factors and emotional factors acting alone or in combination, causing signs and symptoms associated with TMD (Gremillion, 2000).

2.4.3 PNF TECHNIQUES AND THE CRANIOMANDIBULAR SYSTEM

Unfortunately, the use of PNF techniques in the craniomandibular system has not been reported in the literature. For this reason, knowledge concerning this specific use must be developed. Based on the anatomic, biomechanical and physiologic interaction that exists among the muscles involved in the craniomandibular system, a hypothesis can be stated in an attempt to demonstrate the effect of AC and CR techniques on this system. The background information for this hypothesis is given in the following section.

The masseter and temporalis, the suprahyoid and infrahyoid muscles, and the cervical muscles (the upper trapezius, semispinalis capitis, sternocleidomastoid, splenius

capitis, semispinalis capitis, and multifidus) are connected biomechanically, physiologically and functionally due to their working together to maintain the equilibrium of the craniomandibular system. The lever at the level of the head is a first degree lever, which implies that equilibrium between anterior and posterior muscles must exist to maintain the head in the horizontal position. The anterior muscles are the masticatory muscles (masseter, temporalis and pterygoids) and the suprahyoid and infrahyoid muscles. The posterior muscles consist of the trapezius, semispinalis, splenius capitis, longissimus capitis , longissimus cervicis, levator scapulae and multifidus, all of which oppose the resistance caused by the weight of the head (which drops forward to the rotation center of the lever) and the activity of the anterior muscles (as well as masticatory muscles and suprahyoid and infrahyoid muscles). Masticatory muscles are antagonists of the supra- and infrahyoid muscles because the masticatory muscles work in mouth closing and the supra- and infrahyoid muscles as a "functional couple" work in mouth opening (when movement is resisted). Suprahyoid muscles open the mouth while the infrahyoid muscles fix the hyoid bone. On the other hand, the supra- and infrahyoid muscles (as a functional couple) are antagonists to the cervical muscles. For example, when the suprahyoid muscles are activated, as in resisted mouth opening, they cause an anterior momentum due to the greater lever arm related to the center of rotation of the craniocervical system, and this generates a flexor momentum in the cervical spine. Therefore, the posterior cervical muscles are antagonist to this momentum since they cause cervical extension against resistance. Thus, there is a functional connection among these muscles: the masticatory muscles are antagonist to the mouth opening movement; the supra- and infrahyoid muscles (as a functional couple) are agonists for the same

movement, but they are also antagonists to the masticatory muscles. Moreover, the cervical extensor muscles are antagonists of the suprahyoid muscles because the suprahyoid muscles cause flexor momentum in the cervical spine and the cervical extensor muscles cause the opposite momentum (Kapandji 1990; Rocabado 1979). When mouth opening is resisted, the supra- and infrahyoid muscles are activated (suprahyoid muscles open the jaw, and infrahyoid muscles fix the hyoid bone). The masticatory and cervical muscles, based on Sherrington's theory , are inhibited by reciprocal inhibition because, if an agonist muscle contracts, inhibitory neurons immediately send information to the antagonist muscle and cause it to relax . For this reason, the AC technique theorically should cause a relaxation in both the masticatory and cervical muscles (see Figure 6).

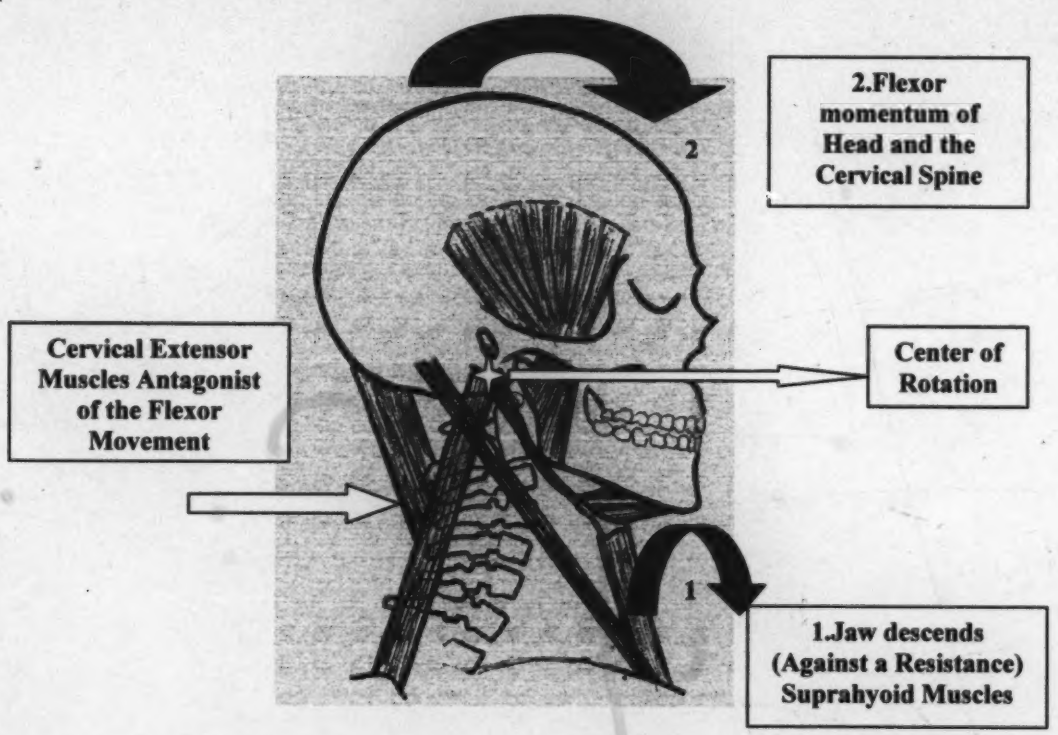

2.Flexor momentum of Head and the Cervical Spine
2
Cervical Extensor Muscles Antagonist of the Flexor Movement
Center of Rotation
1
1.Jaw descends (Against a Resistance) Suprahyoid Muscles

Figure 6: Schematic explanation of the biomechanical connection between suprahyoid muscles and cervical extensor muscles when the mouth opening movement is resisted.

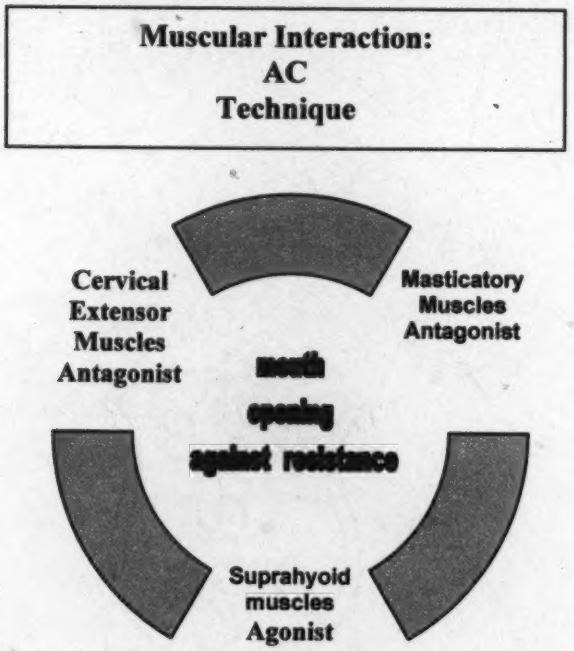


Figure 7: Muscular interaction among masticatory muscles, the supra- and infrahyoid muscles, and cervical muscles: Supra- and infrahyoid muscles are agonists for mouth opening movement, and cervical flexion movement against resistance. Masticatory muscles are antagonist of the suprahyoid and infrahyoid muscles for mouth opening movement (functional couple), and cervical extensor muscles are antagonist of the supra- and infrahyoid muscles for cervical flexion movement.

On the other hand, masticatory muscles (the masseter and temporalis), by contracting, could lead to inhibition of themselves through GTO stimulation, based on the autogenic inhibition principle.

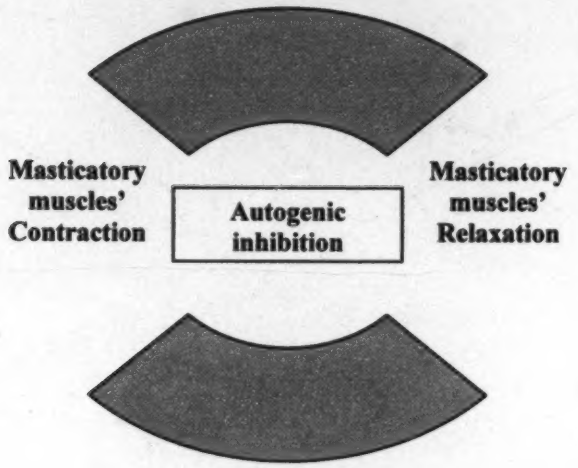


Figure 8: Autogenic Inhibition in masticatory muscles. When an agonist muscles is contracted, after its contraction an inhibition occurs via GTO stimulation (autogenic inhibition).

3. CHAPTER 3: METHODS AND PROCEDURES

3.1 SUBJECTS

A convenience sample of 30 subjects was recruited for this study consisting of, 17 females and 13 males (using α= 0.05 and β= 0.20 power = 80%, and size effect = 0.25; see calculation details in Appendix 3) (Cohen, 1977). Subjects were continually recruited until 30 subjects were found.

3.2 INCLUSION CRITERIA

To be included in this study, the subjects had to:

1. be between 20 and 35 years of age to decrease the degeneration factors that may affect the temporomandibular joint (TMJ), or the cervical spine, and growth factors that might affect the outcomes (Gremillion, 2000).

2. have normal occlusion and an appropriate quality of teeth as evaluated by a dentist. Prior to testing, the subjects were evaluated by a dentist to ensure that the condition of their teeth and occlusion were appropriate for the testing procedures. Specifically, to be included in the study the dentist determined if the subjects had:

- Overjet and overbite ranging from 2 to 4 mm (normal occlusion).
- No anterior or lateral crossbite.
- No root canal treatment to the first molar.

3. have four first molars in mouth

3.3 EXCLUSION CRITERIA:

Subjects were excluded from this study if they had:

1. any acute or chronic injury or systemic disease such as acute pain, diabetes mellitus, or asthma, that could interfere with the outcome.

2. chronic pain or clinical pathology or previous surgery related to the masticatory system or cervical spine and had complaint of symptoms of temporomandibular disorders before the test. Subjects with neurological problems (central or peripheral) that could interfere with the experimental procedure and the outcomes. Patients were evaluated by a physiotherapist prior to testing for ROM, pain in the TMJ and cervical spine, and the posture of craniocervical system to detect any problem or abnormality that could interfere with the outcomes (Appendix 4).

2. any problem or pain in the cervical spine or jaw including patients who had abnormal cervical or jaw range of motion (Magee, 2000).

3. an abnormal cervical or thoracic spine sagittal alignment (Magee, 2000).

(i) Severe forward flexion head position (> 6 cm in malar bone (zygoma)-sternum relation; > 12 cm gravity line, apex cervical spine) (Rocabado, 1979).

(ii) Severe kyphosis (Magee, 2000).

4. been taking medication specifically designed to affect the musculoskeletal system such as anti-inflammatory or pain relief drugs, muscle relaxants or arthritic medications.

5. poor dental condition and abnormal occlusion as evaluated by a dentist.

3.4 SUBJECT RECRUITMENT:

Subjects for this study were recruited from students who attend the University of Alberta using advertising in the Faculty of Rehabilitation Medicine, the University of Alberta Hospital, Faculties of Education, Medicine and Dentistry, and the Student Union building (see Appendix 5). The subjects were informed about the nature of the study and an appointment was made if subjects were willing to participate. Once subjects agreed to participate, they were assessed to determine whether they met the inclusion/exclusion criteria. Subjects were given an informed consent to read, all questions regarding the study were answered, and they signed the informed consent if they were included in the study, in accordance with the University of Alberta's policies on research using human subjects.

3.5 ETHICAL CONSIDERATIONS

This study was relatively risk free. The possibilities of risk were minimized because all the subjects were evaluated by an experienced dentist before doing the procedure, and moreover, the design of the device used for measuring bite force was specially made for biting between the teeth.

3.6 STUDY DESIGN

This study employed a quasi - experimental design using one group as its own control. The AC and CR techniques allowed the possibility to compare the EMG activity before and after the procedure using each subject as his/her own control, so each subject was seen only once. This decreased the potential for subject drop out. Moreover, this design (within subject design) facilitated the comparison among measurements because these measurements came from the same individual, decreasing the possibility of variability error among different subjects (between subject design).

3.7 DATA COLLECTION: GENERAL EXPERIMENTAL PROCEDURE SEQUENCE:

3.7.1 CLINICAL EXAMINATION.

All subjects underwent a clinical examination by a dentist and by one physiotherapist to determine if they met the inclusion or exclusion criteria for this study. If the dentist or physiotherapist felt the subject did not meet the inclusion criteria, the subject was excluded of the study. (see appendix 4 for eligibility of subjects).

3.7.2 DEMOGRAPHIC DATA COLLECTION

Demographic data were collected on all subjects who satisfied the inclusion criteria. These data included age, sex, weight, height and occupation.

3.7.3 DETERMINATION OF ELECTRODE POSITION: MASTICATORY MUSCLES, CERVICAL MUSCLES, AND REFERENTIAL ELECTRODE PLACEMENT

The subjects' skin was cleaned with alcohol and then the electrodes (EL 500 disposable electrodes) were placed on the superficial masticatory muscles (the masseter and anterior temporalis, bilaterally) as described in the protocol of Ferrario et al., (2003), and on the right and left cervical muscles (the upper trapezius, and splenius capitis) as described by Keshner, Campbell, Katz, & Peterson (1989). The interelectrode distance used for all muscles was 2 cm. A reference electrode was placed on the superior part of the sternum. Electrodes were held in place by an adhesive disposable patch during all the experimental procedures. (see Figures 9 and 10)

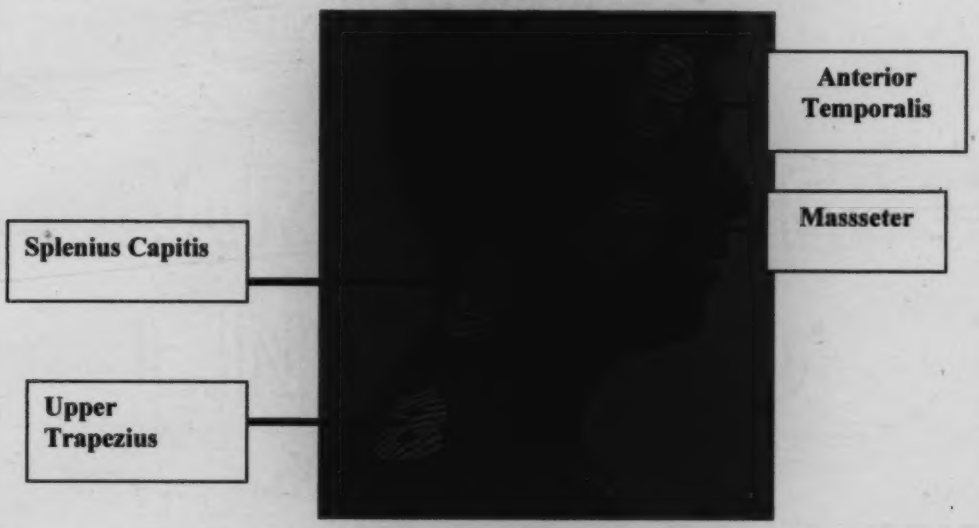


Figure 9: Electrodes position of masticatory muscles and cervical muscles (lateral view).

Figure 10: Electrodes and the connecting leads, with the subject in supine position (superior view)

CERVICAL MUSCLES: Electrodes' position (Keshner et al. 1989):

Trapezius (TRAP): is easily palpated by asking the subject to elevate the shoulders against resistance. Electrodes were located over the palpated muscle belly at the level of C6-C7 and dorsal to the muscle's insertion on the lateral third of the clavicle.

Splenius Capitis (SPLEN CAP): lies underneath the TRAP and sternocleidomastoid (SCM), except for a rectangular area on the lateral portion of the neck where SPLEN CAP is the most superficial muscle. This muscle can be palpated between SCM and TRAP during resisted head extension and lateral rotation in the same direction as the muscle. Electrode placements for the SPLEN CAP muscle were determined by measuring 6 cm rostral to the bony prominence at C7 (approximately the C4 level), 6-8 cm lateral, and palpating for the muscle belly.(see Figure 9 and 11).

Figure 11: Electrode position for cervical muscles (posterior view).

3.7.4. EQUIPMENT FOR MUSCULAR ACTIVITY ASSESSMENT

Muscular activity of the masticatory and cervical muscles was evaluated using an EMG 100C system (BIOPAC Systems: http://biopac.com), which is designed to make the acquisition of EMG signals easy and reliable. This system uses a single differential configuration which is specifically designed to optimally detect EMG signals at the skin surface through disposable electrodes and then the amplifier system rejects common noise signals such as motion and cable artifacts. (See Appendix 6 for specifications of BIOPAC system, amplifier and electrodes characteristics). The data acquisition was sampled at 2000 Hz, and was amplified to 1000 (kilogain).

The EMG activity was analyzed with specific software called Acq*Knowledge*® from BIOPAC systems, Inc., which allowed filtering of the signals obtained and calculating the root mean square (RMS). The obtained data from cervical muscles were filter with a band pass filter (20-500 Hz) and a band stop filter (50-60 Hz).Data obtained from masticatory muscles were band passed at 20-1000 Hz and band stop filtered at 50-60 Hz since the frequency domain of masticatory muscles ranges in this

spectrum(Ferrario et al., 2004). Root mean square was automatically calculated through the Acq*Knowledge*® software for all data and later used for the normalization procedure.

Figure 12: Biopac system for EMG data collection

Calibration of the equipment was performed before testing. Amplitude calibrator Tektronic was used to calibrate the equipment injecting a known voltage source signal and checking the output of the equipment according to the used gain.

3.7.5 MAXIMAL VOLUNTARY REFERENTIAL CONTRACTION (MVRC) ASSESSMENT:

3.7.5.1. NORMALIZATION PROCEDURE:

When using EMG, it is necessary to normalize data by establishing the parameters of the EMG activity of the muscles and the force of the muscles measured in Newtons (maximal voluntary referential contraction). This normalization must be performed before doing any testing, in order to compare data between each subject at different times (De Luca, 1997; Kumar & Mital, 1996). Burden & Barlett (1999) stated that this method

should be used to normalize the amplitude of the EMG if the objectives are to compare these data between subjects, muscles, and tasks, or to retain the natural variation between the individuals.

The recommended method of normalization consists of establishing a relationship between the maximal voluntary referential contraction obtained (in Newtons) and the EMG obtained (RMS value in Volts) (Burden & Barlett, 1999). The Newton value is more stable than the millivolts value since the EMG registers change according to technique (e.g. electrodes placement, skin cleaning, equipment used) (Larivier, Arsenaul, Gravel, Gagnon, & Loisel, 2002, Lehman, 2002).

The chosen normalization procedure was the maximal referential contraction method (MVRC). This procedure was performed for every muscle being analyzed (the masticatory and the cervical muscles). When the maximal voluntary contraction was evaluated, the subjects exerted a force in Newtons, which caused EMG activity to be recorded in Volts (calculated RMS).The maximal EMG value obtained when the subject exerted the maximal force was used to obtain a normalized EMG activity.

This normalization process, as mentioned previously, was necessary to compare measurements between subjects over time (Burden & Barlett, 1999; De Luca, 1997).

3.7.5.2. GENERAL PROCEDURE TO MEASURE THE MVRC

The procedure to measure the MVRC was as follows:

The subjects were asked to perform a warm up, which consisted of two movements of the neck and head in all directions (flexion, extension, side flexion, and

rotation) and ten movements of opening and closing the mouth. Following warm up, the subjects were placed in a supine position on a bed. The subjects were asked to position their head in a normal position directing their eyes at a point in front of them and focus there (standardized position of the head). The upper and lower extremities were relaxed in the resting position.

3.7.5.2.1. MVRC MASTICATORY MUSCLES ASSESSMENT

The masticatory muscles force was measured with a specific device (see Appendix 7) that contained a miniature load cell (Figure 13) (see the characteristics of this tool in Appendix 8).

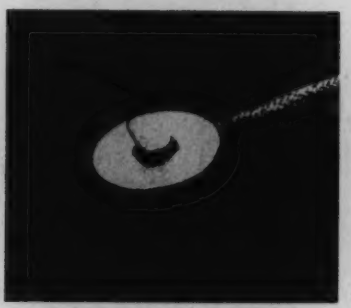


Figure 13: Miniature load cell for measuring bite force

This device was built of stainless steel and was covered with a disposable piece of polyethylene tubing and a glove (for each subject) to allow the subjects to bite over it and protect their teeth. The device was placed on the first mandibular molar by the evaluator's hand, which was covered with a disposable glove to maintain the normal hygiene of the patient's mouth. (See Figures 14-15).

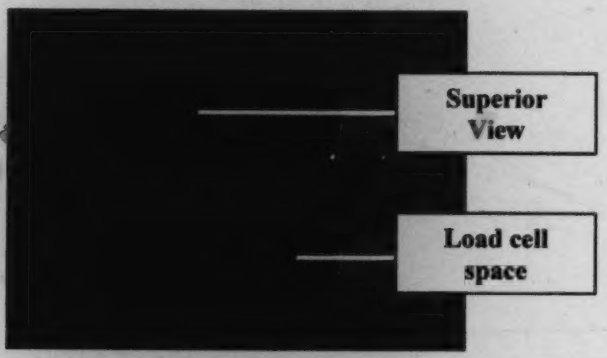


Figure 14: Device which contains the load cell

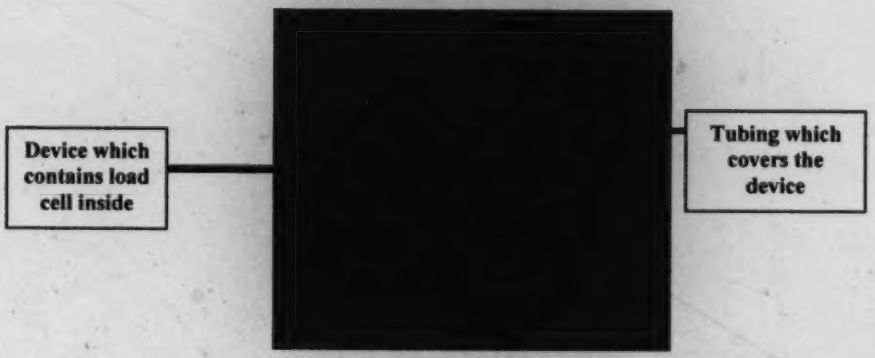


Figure 15: Device and tubing used to measure bite force

To measure the bite force on one side (right or left side), the device was placed over the first molar region. At the beginning of the test, each subject was asked to bite without any measurements being taken so the subject could become familiar with the equipment. After this training period, and when the subject felt comfortable with the procedure, the testing protocol started.

The MVRC of the masticatory muscles was evaluated by asking each subject to close his/her mouth from the rest position, while pressing the load cell contained in the specific device for this purpose. The sensor located in the load cell measured the amount

of force of the masticatory muscles. The time of contraction was 5 seconds and a rest of 3 minutes between trials was used to avoid the effect of fatigue (Jensen & Westgard, 1995).

Each subject then performed 2 contractions in each region (left and right first molar) and the force and EMG activity was registered simultaneously. The average of the highest measurements was considered for the normalization procedure (see below). The data of the amount of force produced (in Newtons and millivolts) was saved in a computer.

Figure 16: Bite force device in place on first molars for data collection.

The miniature load cell was calibrated with known weights obtaining a linear curve. The values of calibration were entered into the computer and used with Acq*Knowledge*® software for doing the normalization procedure.

3.7.5.2.2. MVRC CERVICAL EXTENSOR MUSCLES ASSESSMENT

The MVRC for the cervical muscles was measured with a different load cell (see characteristics in Appendix 9), but with a specific system adapted to the cervical spine (see Figures 17 to 19).

The MVRC of the cervical muscles was obtained with the subjects placed in a supine position. The subjects were asked to locate their head in the neutral position (standardized head posture). The subjects were then asked to push backward (extend the head) for 5 seconds with maximal effort against the load cell, which registered the force (Figure 17). This procedure was performed with a specific system designed to evaluate cervical muscle force and was comprised of straps for head support, and a cable to connect the head straps with the load cell (see Figures 17 to 19). The subjects were trained in the correct movement before the testing. When the subject felt familiar with the protocol, the testing started. This procedure was repeated 3 times and the average of the measurements was used for normalization. Three minutes of rest were used between trials to avoid the effect of fatigue (Jensen & Westgaard, 1995). This evaluation was done only to normalize the data (Mc Lean, 2003).

The load cell used to measure the cervical strength was calibrated with known weights obtaining a linear curve. The values of calibration were entered to the computer and used with Acq*Knowledge*® software for doing the normalization procedure.

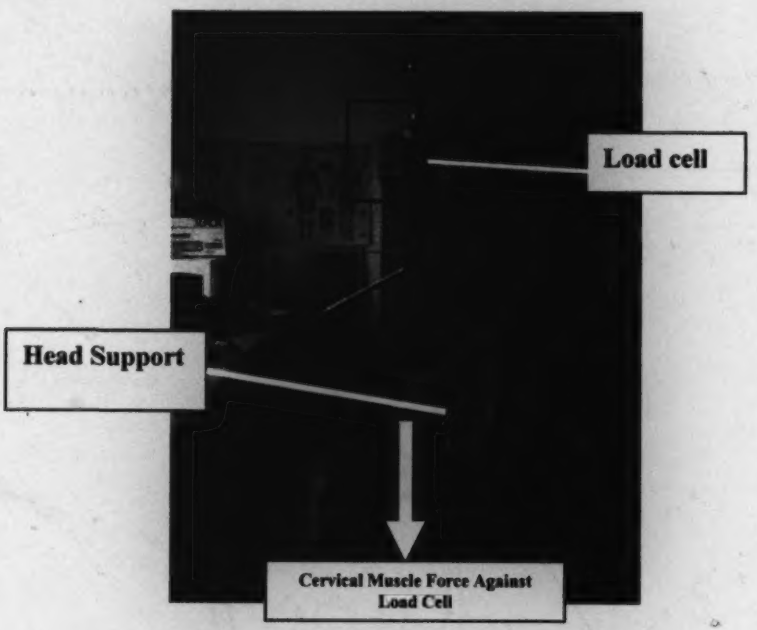


Figure 17: Straps and load cell for measuring cervical extensor MVRC

Figure 18: Patient's position (lateral view) MVRC cervical extensor muscles evaluation. arrow shows the direction that subject pushes, extending head.

Figure 19: Patient's position (cranial view)
MVRC extensor cervical muscles evaluation.
arrow shows the direction that subject pushes, extending head.

3.7.6 MUSCULAR ACTIVITY ASSESSSMENT WHEN AC AND CR TECHNIQUE ARE APPLIED:

The following procedures were performed in the supine position on a bed. The patients were asked to position their head in a normal position directing their eyes at a point in front of them (standardized position of the head) (Cook, 1988). The upper and lower extremities were relaxed in the resting position.

Before performing the first evaluation, the subjects were asked to exert the maximum force during a mouth opening movement against resistance, to evaluate the

maximum force of the suprahyoid muscles. This value was the 100% of the force and was registered by digital dynamometer (The Manual Muscle Test System) (Mulroy, Lassen, Chambers, & Perry, 1997; Ottenbacher, Branco, Gonzales, Peek, & Hinman, 2002) (see Appendix 10), that the evaluator located on the chin of the patient (see Figure 20). This value was a reference value when the AC procedure was performed since it was necessary to ask for a 25-30% of the MVRC when this technique was applied. The subject was trained in the procedure before starting the testing. When the subject was able to perform the procedure correctly, the testing started. The test was performed twice and the average of this value was used as a reference value. Each contraction lasted 5 seconds and, before starting the next evaluation, a rest of 3 min was needed between trials to avoid the effect of fatigue (Jensen & Westgaard, 1995).(see Fig 20). For more details about the procedures see Figure 21

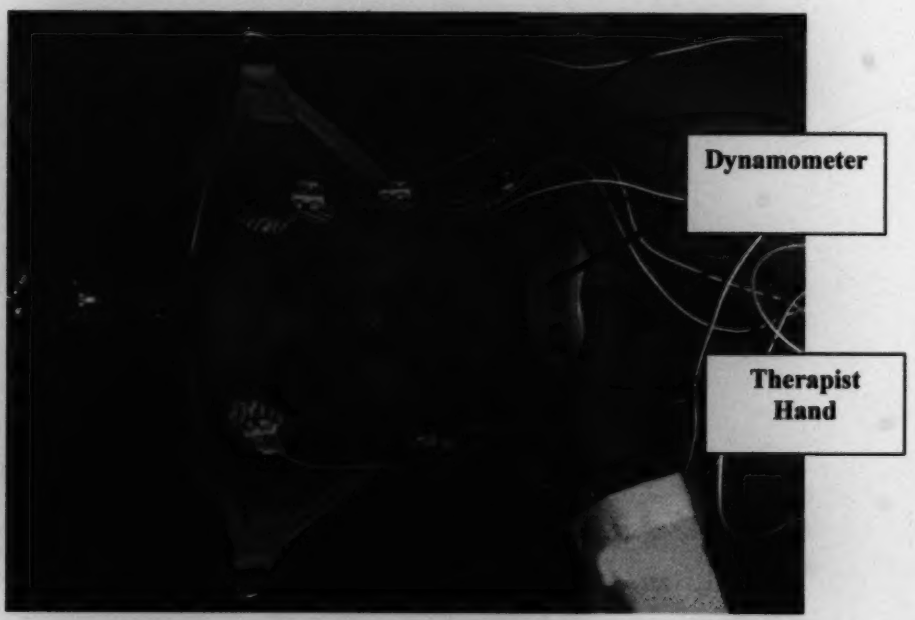


Figure 20: Resistance provided by the therapist and registered with a dynamometer.

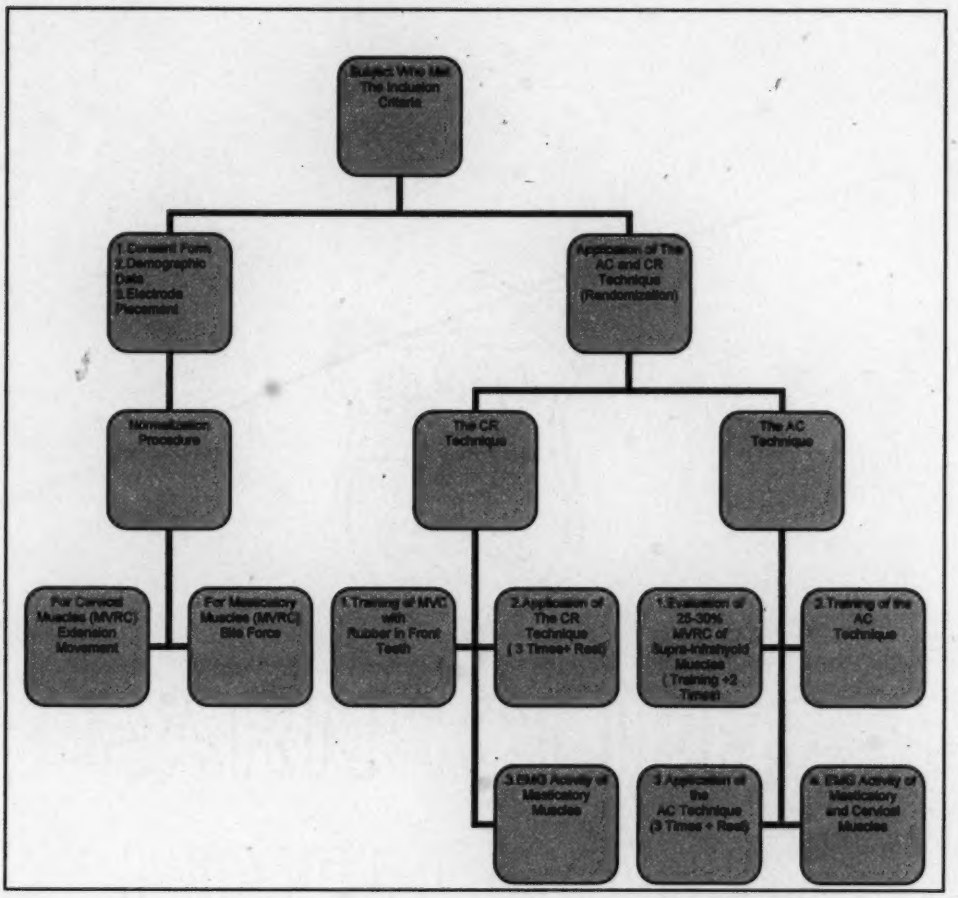

Subject Who Met The Inclusion Criteria
1.Consent Form 2.Demographic Data 3.Electrode Placement
Application of The AC and CR Technique (Randomization)
Normalization Procedure
The CR Technique
The AC Technique
For Cervical Muscles (MVRC) Extension Movement
For Masticatory Muscles (MVRC) Bite Force
1.Training of MVC with Rubber in Front Teeth
2.Application of The CR Technique (3 Times+ Rest)
1.Evaluation of 25-30% MVRC of Supra-Infrahyoid Muscles (Training +2 Times)
3.Training of the AC Technique
3.EMG Activity of Masticatory Muscles
3.Application of the AC Technique (3 Times + Rest)
4. EMG Activity of Masticatory and Cervical Muscles

Figure 21: Flow chart with details about sequence of experimental procedure

The first EMG evaluation performed in order to evaluate the effectiveness of the AC and CR technique was performed in the resting position of the jaw and cervical spine. In this position, the EMG activity of the selected muscles was measured (5 seconds). Then, a randomized selection was determined as to whether the subject would receive the AC technique or CR technique first to avoid sequencing bias. Each subject received both

techniques, but the order of each was randomized. The time between both techniques was 3 minutes (Jensen & Westgaard, 1995).

For the second evaluation, the subject was asked to open his/ her mouth (rotational opening) pressing against the resistance given by the therapist, maintaining 25% MVC in this position for at least 10 seconds (the level of contraction was controlled by a dynamometer applied on the chin of the patient, which registered the force exerted for the suprahyoid muscles) in an attempt to cause reciprocal inhibition (Leonard et al. 1999). The subject was told when he/she reached the level required and was asked hold this level for 10 seconds. During this time, when the AC technique was applied, the EMG activity of the masticatory and cervical muscles was registered. The subjects practiced the procedure before testing. When the subjects felt confident with the procedure, the test started (Figure 20).

If the random selection decided that the CR technique were applied, the subjects were asked to generate the maximum force biting a rubber (disposable, specifically built to be used with food) in the anterior-intermediate teeth (CR technique) and to maintain this contraction for 10 seconds. The subjects had a training period before doing the test in order to be familiar with the test. While the subject was contracting maximally, the EMG was not registered as an outcome, because the effect of this technique occurs after the contraction. (see Figure 22).

Figure 22: Patient and rubber's position for the CR technique.

The third measurement was taken after the contraction of the suprahyoid muscles was completed (following the AC technique) or after masticatory muscles contraction was finished (CR technique) and lasted 10 seconds.

This sequence was repeated 3 times for every subject, with a 3 minute rest between each trial to avoid the possible confounding effect of fatigue (for both AC and CR techniques) (Jensen & Westgaard, 1995).

When the experimental procedure was finished, the electrodes were removed from the subject and the subject was asked to return to a sitting position, rest for 5 minutes and was told he or she was finished and could leave.

The procedure was performed in the Biomechanics laboratory in the Faculty of Rehabilitation Medicine. The experimenter (a physiotherapist with 8 years of experience in clinical practice) applied the procedure to all subjects. The procedure took

approximately 1 1/2 – 2 hours to complete and the measurements were performed all on the same day for each subject (Details for data collection sheet see Appendix 11).

3.8 STATISTICAL ANALYSIS

The data on the EMG activity of all muscles were analyzed descriptively (e.g. mean, standard deviation). A one way ANOVA with repeated measures was performed to see if there were any differences between right and left sides in each pair of muscles (the masseter, the anterior temporalis, the splenius capitis and the upper trapezius). If there were no differences, the data would be condensed to make the statistical analysis easier.

To cover the first objective, a 2 factor ANOVA with repeated measures (2 independent variables : muscles and the AC technique [time]) test was used to evaluate the differences in EMG activity for selected muscles (dependent variable: EMG activity of the upper trapezius, the splenius capitis, the anterior temporalis and the masseter) among three conditions (before – during – after the AC technique), and a 2 way ANOVA with repeated measures test (2 independent variables : technique [AC technique and CR technique] , and muscles [the masseter and the anterior temporalis]) to evaluate the EMG activity differences between both techniques (the CR and the AC technique) in masticatory muscles (the masseter and the anterior temporalis). Paired comparisons were administered to evaluate the differences between variables. The level of significance was set at $\alpha = 0.05$. The statistical procedures were analyzed by the researcher. The SPSS Statistical Program version 11.0 (Statistical Package for the Social Sciences) was used to perform the statistical analysis.

4. CHAPTER 4: RESULTS

The present study examined the results of the effect of two different proprioceptive neuromuscular facilitation techniques in the activity of the masticatory muscles (the masseter and the anterior temporalis muscles) and the cervical muscles (the upper trapezius and the splenius capitis) among normal subjects without temporomandibular joint or craniocervical pathologies. All participants were between 18 and 35 years of age. All subjects were carefully screened according to the established inclusion/exclusion criteria. Each participating subject was informed of his/her rights and with full disclosure of the benefits and risks of the study.

4.1 SUBJECTS CHARACTERISTICS

Forty-eight subjects were screened and thirty subjects were finally included in this study; seventeen females and thirteen males. 18 subjects were dropped from this study because: 14 did not meet the inclusion criteria, 3 subjects had poor quality EMG data, and the data obtained from 1 subject was not recognized by the format of the software program. The demographic descriptive statistics for all 30 subjects is listed below.

4-1 Height, Weight, and Age

Table 4-1 presents the mean and standard deviation of height, weight and age for all 30 subjects and by gender (female and male).

Table 4-1: Descriptive Statistics for Study Subjects Height, Weight and Age.

Subjects	Height (m)		Weight (Kg)		Age	
	Mean	SD	Mean	SD	Mean	SD
All subjects	1.667	±0.089	65.107	±11.889	25.1	±3.009
Males	1.755	±0.049	72.753	±7.215	26.461	±2.913
Females	1.600	±0.045	59.288	±11.281	24.058	±2.703

Height was measured in meters, weight in kilograms, and age in years.

4.2 NORMALIZED ELECTROMYOGRAPHIC ACTIVITY FOR ALL SUBJECTS FOR ANTAGONIST CONTRACT-AGONIST RELAX (AC) TECHNIQUE.

The Table 4-2 presents the mean and standard deviation of normalized EMG activity for all masticatory muscles (the masseter and the anterior temporalis) and the cervical muscles (the splenius capitis and the upper trapezius) for all 30 subjects before, during and after AC technique.

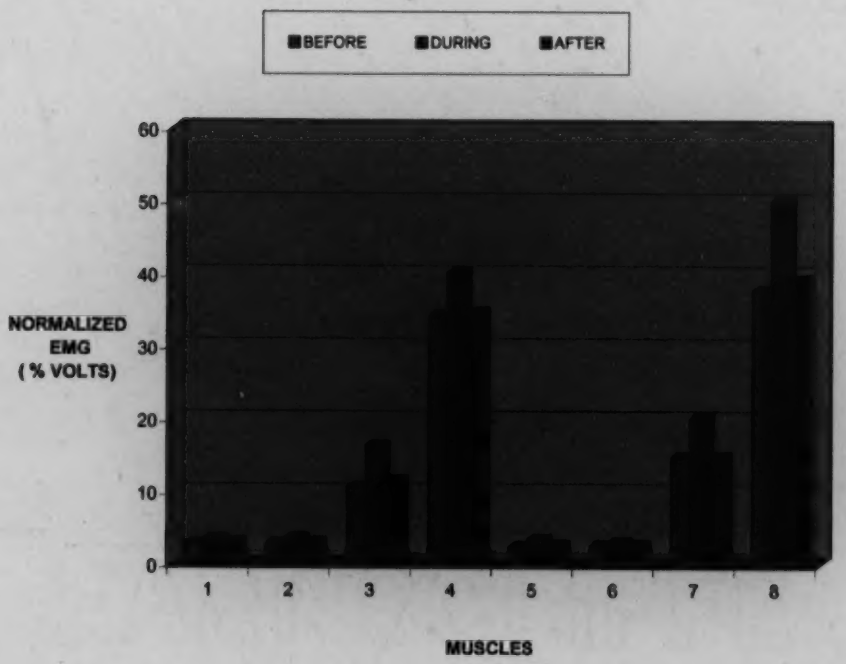
TABLE 4-2 Mean and Standard Deviation of Normalized EMG Activity of all Muscles for All Subjects Before, During and After the AC Technique.

Muscles	AC Technique					
	Before		During		After	
	Mean	SD	Mean	SD	Mean	SD
Masseter left	2.918	2.289	3.564	2.570	3.118	2.418
Ant Temporalis Left	2.591	2.164	3.656	2.808	3.137	2.208
Splenius Capitis Left	10.699	8.942	16.393	11.376	11.606	9.201
Upper Trapezius Left	24.361	27.182	40.193	33.396	24.758	25.759
Masseter Right	2.499	2.138	3.4716	3.059	2.751	2.128
Ant Temporalis Right	2.841	1.848	3.089	2.261	2.707	1.834
Splenius Capitis Right	14.857	15.880	20.108	19.041	14.856	15.335
Upper Trapezius Right	37.795	25.930	50.122	32.820	33.184	26.189

Normalized EMG values are percentages of the maximum reference contraction (in volts)

Figure 23 shows the mean of normalized EMG activity for the masticatory muscles and the cervical muscles, before, during, and after the AC technique.

Figure 23: Mean of Normalized EMG activity for All Masticatory Muscles and Cervical muscles, Before, During, and After the AC Technique



Key:

1	*= Masseter Left*	*5*	*= Masseter Right*
2	*= Anterior Temporalis Left*	*6*	*= Anterior Temporalis Right*
3	*= Splenius Capitis Left*	*7*	*= Splenius Capitis Right*
4	*= Upper Trapezius Left*	*8*	*= Upper Trapezius Right*

**Normalized EMG values are percentages of the maximum reference contraction (in volts)*

4.3 MEAN DIFFERENCES (BEFORE-AFTER) OF NORMALIZED EMG ACTIVITY OF MASTICATORY MUSCLES (MASSETER AND ANTERIOR TEMPORALIS) FOR THE CR AND THE AC TECHNIQUE

Table 4-3 shows the mean differences (before – after) and standard deviation of normalized EMG activity of all masticatory muscles (the masseter and the anterior temporalis) for the CR and the AC technique.

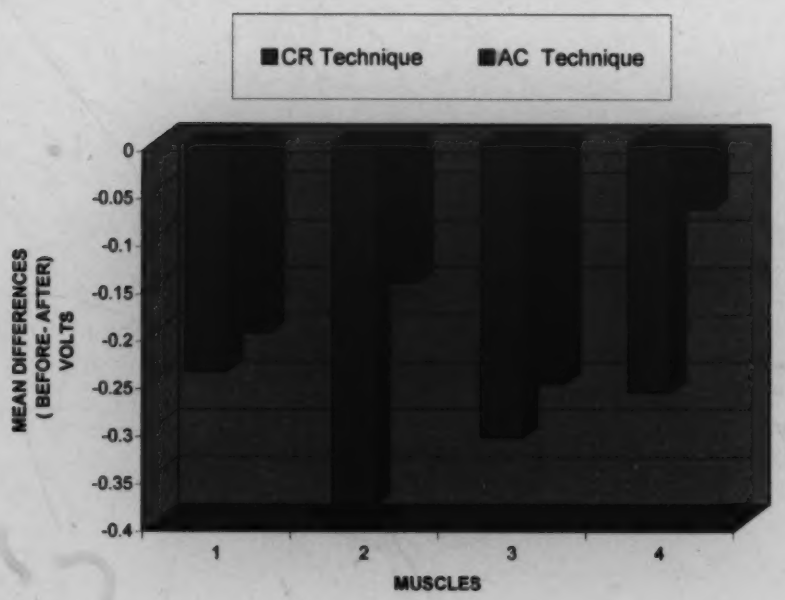
TABLE 4-3 Mean Differences (before – after) and Standard Deviation of Normalized EMG Activity of all Masticatory Muscles (the masseter and the anterior temporalis) for the CR and the AC Technique.

Technique	Mean differences of Normalized EMG activity (before and after applying each technique)			
	Masseter left	Temporalis left	Masseter right	Temporalis right
CR Technique	-0.249	-0.350	-0.359	-0.261
AC Technique	-0.199	-0.146	-0.252	-0.068

Normalized EMG values are percentages of the maximum reference contraction (in volts)

Figure 24 presents the mean differences of normalized EMG activity of all masticatory muscles for CR and AC technique.

Figure 24: Mean Differences of Normalized EMG (Before- After) of Masticatory Muscles for the CR and the AC Technique.



Key:

1	*= Masseter Left*	*3*	*= Masseter Right*
2	*= Anterior Temporalis Left*	*4*	*= Anterior temporalis Right*

**Normalized EMG values are percentages of the maximum reference contraction (in volts)*

4.4 COMPACTION OF VARIABLES

It was decided to perform one way ANOVA with repeated measures analysis on each pair of muscles, each condition, and each technique to see if there were differences between muscles on the right side compared with the left side in order to condense variables and to make the analysis easier. A one way ANOVA with repeated measures and pair wise comparisons demonstrated no significant differences ($p<0.05$) between

right and left side for all pairs of muscles for the AC technique and the CR technique. Because there were no significant differences, it was decided to condense all variables and concentrate right and left into one common variable containing the mean of right and left sides.

The mean differences between each pair of muscles in all different conditions for the AC technique were not significant for most muscles (the masseter activity before $p<0.318$; the anterior temporalis activity before $p< 0.213$; the splenius capitis before $p<0.048$; the upper trapezius activity before $p < 0.276$; the masseter activity during $p<0.866$; the anterior temporalis activity during $p<0.078$; the splenius capitis activity during $p < 0.169$; the upper trapezius activity during $p < 0.066$; the masseter activity after $p < 0.423$; the anterior temporalis after $p< 0.92$; the splenius capitis activity after $p< 0.327$; and the upper trapezius activity after $p<0.163$). Only the splenius capitis obtained a significant difference between right and left sides, however, the analysis was performed considering it as one variable as the rest of the muscles, because it was considered not relevant to make the analysis for each side only in this muscle.

Table 4-41 Pair wise Comparisons for Each Pair of Muscle (Left and Right).

Muscle Pair	*Before*		*During*		*After*	
	Mean diff	Significance	Mean diff	Significance	Mean diff	Significance
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Anterior Temporalis left - Anterior Temporalis right	0.351	0.213	0.606	0.332	0.386	0.295
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Upper Trapezius left -Upper Trapezius right	-3.438	0.276	-9.928	0.066	-4.430	0.163

Normalized EMG values are percentages of the maximum reference contraction (in volts)

The one way ANOVA with repeated measures analysis and paired comparisons for the mean differences (before-after) for each pair of masticatory muscle (left and right) for the CR technique were also not statically significant $p<0.05$ (mean differences EMG activity [before –after] for the masseter-CR technique $p< 0.390$; mean differences EMG activity [before –after] for the anterior temporalis-CR technique $p< 0.638$; mean differences EMG activity [before –after] for the masseter-AC technique $p<0.487$; and mean differences EMG activity [before –after] for the anterior temporalis-AC technique $p< 0.341$).

Table 4-42 Pair wise Comparisons for Each Pair of Muscle (Left and Right) for the AC and the CR Technique.

Technique	Muscle Pair	Mean diff	Significance
AC Technique	Masseter left - Masseter right	0.054	0.487
	[illegible]	[illegible]	[illegible]
CR Technique	Masseter Left-Masseter Right	0.070	0.390
	[illegible]	[illegible]	[illegible]

Normalized EMG values are percentages of the maximum reference contraction (in volts)

Therefore, based on this analysis, it was decided to condense muscles pairs into only one variable in order to make the statistical analysis easier. For example, instead of considering right and left masseter as separate variables, only the mean of both was considered and the variable was called masseter as a group (including left and right side).

Table 4-43 presents the mean and the standard deviation for all the variables as a group regardless right or left side for the AC technique.

TABLE 4-43 Combined (left and right) Mean and Standard Deviation of Normalized EMG Activity for the Masticatory Muscles and Cervical muscles, Before, During, and After the AC Technique.

Variable	N	Mean	Standard Deviation
Masseter activities (right and left together) before AC technique	30	4.167	2.958
Anterior Temporalis activities (right and left together) before AC technique	30	4.310	1.927
Splenius Capitis activities (left and right together) before AC technique	30	18.127	15.753
Upper Trapezius activities (left and right together) before AC technique	30	53.261	38.380
Masseter activities (left and right together) during AC technique	30	5.300	3.530
Anterior Temporalis activities (left and right together) during AC technique	30	5.249	3.745
Splenius Capitis activities (left and right together) during AC technique	30	26.447	19.027
Upper Trapezius activities (left and right together) during AC technique	30	65.254	43.863
Masseter activities (left and right together) after Ac technique	30	4.493	3.020
Anterior Temporalis activities (left and right together) after AC technique	30	4.430	2.175
Splenius Capitis activities (left and right together) after AC technique	30	19.034	15.693
Upper Trapezius activities (left and right together) after AC technique	30	54.349	36.939

Normalized EMG values are percentages of the maximum reference contraction (in volts)

Table 4-44 presents the combined mean (left and right) of differences (before-after) and standard deviation for masticatory muscles for the AC and the CR technique.

TABLE 4-44 Combined Mean (Left and Right) of Differences (Before-After) and Standard Deviation of Masticatory Muscles for the AC and the CR Technique.

	N	After	SD
Combined mean of differences (before-after) masseter activity for the CR technique	30	-0.394	0.653
[illegible] activity for the CR technique	[illegible]	[illegible]	[illegible]
Combined mean of differences (before-after) masseter activity for the AC technique	30	-0.325	0.538
[illegible] the AC technique	[illegible]	[illegible]	[illegible]

Normalized EMG values are percentages of the maximum reference contraction (in volts)

4-5 NORMALIZED EMG ACTIVITY FOR DIFFERENT TIME (BEFORE DURING AND AFTER) FOR AC TECHNIQUE ANALYSIS

A two way ANOVA with repeated measures analysis demonstrated that there were significant differences in normalized EMG activity among before, during, and after the AC technique, and there were also significant differences in muscle activity. Moreover, there was a significant interaction between time and muscles. Table 4-51 presents the F value and the significance value for all variables.

TABLE 4-51 A Two Way ANOVA with Repeated Measures Analysis for Normalized EMG Activity for all Muscles, Before, During, and After the AC Technique (F summary Table).

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME (Before , During , and After)	2255.016	2	1127.508	47.452	0.000 (*)
Error (TIME)	1378.135	58	23.761		
MUSCLES	168335.331	3	56111.777	51.294	0.000 (*)
Error (MUSCLES)	6171.323	83	1093.933		
TIME X MUSCLES	1669.481	6	278.247	19.438	0.000 (*)
Error (TIME)(MUSCLES)	3098.715	174	14.314		

Significant level < 0.05
(*) Significant difference
Sphericity Assumed (means homogeneity of variance): The variance of the differences among different conditions should be equivalent (in the population sampled) in order to produce a more accurate significance (p) value.

The pair wise comparisons between different times of the AC technique demonstrated that there were significant differences among before, during, and after the AC technique ($p < 0.05$). The activity of the muscles was different before, compared with during and after the application of the AC technique.

TABLE 4-52 Pair Wise Comparisons between Different Times of the AC Technique.

(I) TIME	(J) TIME	Mean Difference (I-J)	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a)	
					Lower Bound	Upper Bound
BEFORE	DURING	-5.594(*)	.738	.000*	-7.168	-4.019
	AFTER	-0.625(*)	0.240	0.014*	-1.116	-0.134
DURING	BEFORE	5.594(*)	.738	.000*	4.019	7.168
	AFTER	4.969(*)	0.738	0.000*	3.461	6.477
AFTER	BEFORE	0.625(*)	0.240	0.014*	0.134	1.116
	DURING	-4.969(*)	.738	.000*	-6.477	-3.461

Normalized EMG values are percentages of the maximum reference contraction (in volts)
Based on estimated marginal means
( )The mean difference is significant at the 0.05 level.*
Bound= Boundary

The pair wise comparisons among muscles demonstrated that there were significant differences in normalized EMG activity among muscles when applying the AC technique. The summary is presented in Table 4-53.

TABLE 4-53 Pair wise Comparisons of Normalized EMG Activity among Masticatory Muscles and Cervical Muscles for the AC Technique.

MUSCLES	MUSCLES	Difference (I-J)	Error		95% Confidence Interval for Difference(a)	
					Lower Bound	Upper Bound
	Splenius Capitis	-16.550(*)	2.899	0.000	-22.478	-10.621
Ant Temporalis	Masseter	0.027	0.510	0.959	-1.016	1.069
	Upper Trapezius	-52.941(*)	6.885	0.000	-67.023	-38.860
	Anterior Temporalis	16.523(*)	2.926	0.000	10.538	22.508
Upper Trapezius	Masseter	52.968(*)	7.046	0.000	38.557	67.379
	Splenius Capitis	36.418(*)	5.620	0.000	24.925	47.912

Normalized EMG values are percentages of the maximum reference contraction (in volts)
Based on estimated marginal means
( )The mean difference is significant at the 0.05 level.*
Bound= Boundary

These data show that muscles behaved differently from one another and their activities are significantly different.

The activity of the muscles in each condition is summarized in Table 4-54.

TABLE 4-54 Normalized EMG activity of All muscles Before, During and After the AC Technique.

[illegible]					
				Lower Bound	*Upper Bound*
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Anterior Temporalis	4.310	.592	3.133	5.488
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Upper Trapezius	53.261	7.269	38.813	67.709
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Anterior Temporalis	5.240	.592	4.063	6.418
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Upper Trapezius	65.254	7.269	50.807	79.702
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Anterior Temporalis	4.490	.592	3.313	5.667
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Upper Trapezius	54.349	7.269	39.901	68.797

Normalized EMG values are percentages of the maximum reference contraction (in volts)
Bound= Boundary

A one way ANOVA with repeated measures was run only to clarify if there were significant differences between each pair of muscles at different times of the AC technique. For more details see Tables 4-55, 4-56, 4-57, 4-58.

TABLE 4-55 Pair wise Comparisons for the Masseter Muscle Before, During, and After the AC Technique.

TIME MUSCLE	TIME MUSCLE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
Masseter Before	Masseter During	1.153(*)	0.235	0.000	0.643	1.663
	Masseter After	-.326(*)	0.098	0.002	-0.527	-0.125
Masseter During	Masseter After	-1.479(*)	0.241	0.000	-1.991	-0.968

Normalized EMG values are percentages of the maximum reference contraction (in volts)
Based on estimated marginal means
(*) The mean difference is significant at the .05 level.
Bound= Boundary

TABLE 4-56 Pair wise Comparisons for the Anterior Temporalis Muscle Before, During, and After the AC Technique

TIME MUSCLE	TIME MUSCLE	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
Anterior Temporalis Before	Anterior Temporalis During	-1.538(*)	0.270	0.000	-2.112	-0.964
	Anterior Temporalis After	-0.180	0.141	0.213	-0.468	0.109
Anterior Temporalis During	Anterior Temporalis After	1.358(*)	0.253	0.000	0.841	1.875

Normalized EMG values are percentages of the maximum reference contraction (in volts)
Based on estimated marginal means
(*) The mean difference is significant at the 0.05 level.
Bound= Boundary

TABLE 4-57 Pair wise Comparisons for the Splenius Capitis Muscle Before, During, and After AC Technique.

[illegible] MUSCLE	[illegible] MUSCLE	Mean Difference (I-J)	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a)	
					Lower Bound	Upper Bound
Splenius Capitis before	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Splenius Capitis After	**-.907(*)**	**0.225**	**0.000**	**-1.367**	**-0.447**
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Normalized EMG values are percentages of the maximum reference contraction (in volts)
Based on estimated marginal means
(*) The mean difference is significant at the 0.05 level.
Bound= Boundary

TABLE 4-58 Pair wise Comparisons for the Upper Trapezius Muscle Before, During, and After AC Technique

[illegible] MUSCLES	[illegible] MUSCLES	Mean Difference (I-J)	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a)	
					Lower Bound	Upper Bound
Upper Trapezius Before	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Upper Trapezius After	**-1.088**	**0.742**	**0.153**	**-2.606**	**0.429**
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

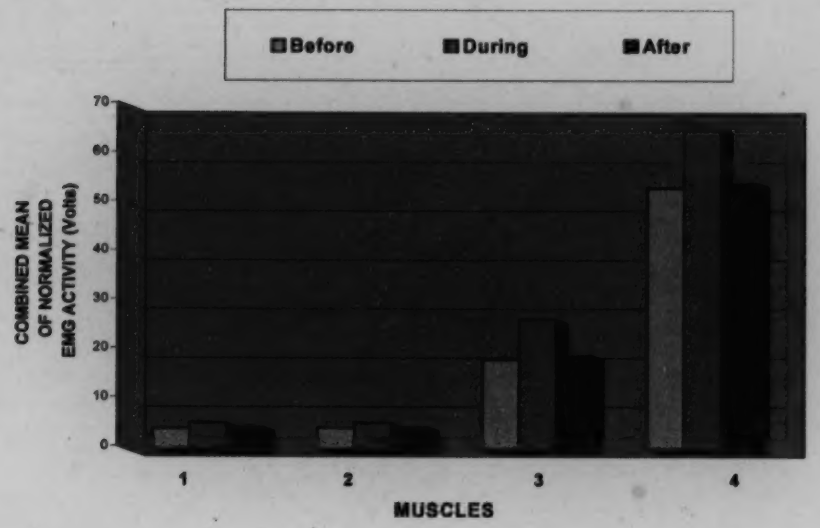
Normalized EMG values are percentages of the maximum reference contraction (in volts)
Based on estimated marginal means
(*) The mean difference is significant at the 0 .05 level.
Bound= Boundary

The analysis demonstrated that there was significantly different EMG activity between before and during, and also between during and after the AC technique for all the muscles (the masticatory muscles and the cervical muscles) at different times. For

example, for the masseter muscle, there was a significantly different EMG activity between before, during, and after as well as for the splenius capitis. However, for the anterior temporalis and the upper trapezius, there was no statistical difference between before and after the AC technique. Analyzing the mean of each muscle EMG activity (Table 4-54) shows that the activity for all muscles increased during the application of the AC technique compared with before and after the technique. However, the activity of masticatory muscles increased in lesser proportion than the cervical muscles.

Figure 25 presents the combined mean EMG activity for all pairs of muscles (the masseter, the anterior temporalis, the splenius capitis, and the upper trapezius) before, during and after AC technique.

Figure 25: Combined Mean EMG activity for the Masticatory and the Cervical Muscles (left and right side together), Before, During, and After the AC Technique.



Key:

1	*=Masseter*	*3*	*=Upper Trapezius*
2	*=Anterior Temporalis*	*4*	*=Splenius Capitis*

Normalized EMG values are percentages of the maximum reference contraction (in volts).

Analyzing the Figure 25, it is noticed that all muscles increased their activity during the AC technique. This increase in the normalized EMG activity during the application of the AC technique of the masticatory muscles and cervical muscles was statistical significant for all muscles. (See Tables 4-55, 4-56, 4-57, and 4-58).

4-6 ANALYSIS OF DIFFERENCES (BEFORE –AFTER) OF NORMALIZED EMG ACTIVITY OF MASTICATORY MUSCLES FOR THE AC AND THE CR TECHNIQUE.

A two way ANOVA with repeated measures analysis (technique [the AC and the CR] and muscles) demonstrated that there were no significant differences in the differences of normalized EMG activity (before- after) between the masticatory muscles for the AC and the CR techniques. There were no significant differences between each technique (AC and CR) and between muscles (the masseter and the anterior temporalis). Table 4-61 presents the F value and the significance value for all variables.

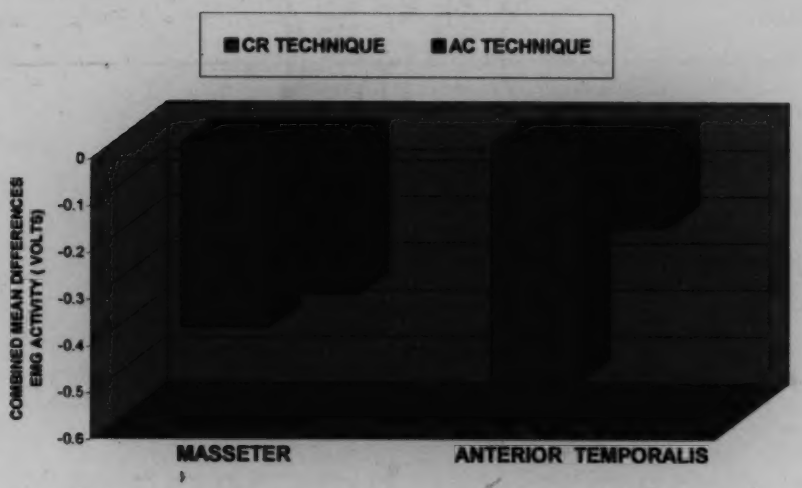
TABLE 4-61 A Two Way ANOVA with Repeated Measures Analysis of Differences (before –after) of Normalized EMG Activity of Masticatory Muscles for the AC and the CR technique

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
TECHNIQUES (AC and CR)	1.201	1	1.201	1.431	0.241
Error (TECHNIQUES)	24.554	29	0.839		
MUSCLES	0.006	1	0.006	0.010	0.921
Error (MUSCLES)	16.913	29	0.583		
TECHNIQUES X MUSCLES	0.512	1	0512	2.485	0.126
Error (TECHNIQUES X MUSCLE)	5.971	29	0.206		

Figure 26 presents the combined mean (left and right) of the differences (before-after) of normalized EMG activity for masticatory muscles (the masseter and the anterior temporalis) for the CR and the AC technique. Analyzing the Figure 26 shows that both

techniques increased the activity of the masticatory muscles (the masseter and the anterior temporalis) after the application of each technique, nevertheless, the CR technique increased the normalized EMG muscles activity in greater magnitude than the AC technique.

Figure 26: Combined Mean (left and right) of the Differences (before-after) for the Masticatory Muscles (the Masseter and the Anterior Temporalis) for the CR and the AC Technique.



Normalized EMG values are percentages of the maximum reference contraction (in volts)

5. CHAPTER 5: DISCUSSION

PNF techniques have been used in the physiotherapy field for many years to cause relaxation and improve muscle flexibility (Carter, Kinzey, Chitwood, & Cole, 2000; Condon & Hutton, 1987; Etnyre et al., 1986; Etnyre & Abraham, 1986; Etnyre & Lee, 1988; Ferber et al., 2002; Godges, Mattson-Bell, Thorpe, Shan, 2003; Lucas and Koslow, 1984; Osternig et al., 1990; Osternig et al., 1987). The knowledge that exists about the effectiveness of the PNF technique in causing muscular relaxation has been questioned (Condon & Hutton, 1987; Etnyre et al., 1986; Etnyre & Abraham, 1986; Etnyre & Lee, 1988; Ferber et al., 2002; Osternig et al., 1990; Osternig et al., 1987). Some studies have found that the EMG activity of muscles when doing a PNF technique is not decreased or even increased (Condon & Hutton, 1987; Etnyre et al., 1986; Etnyre & Abraham, 1986; Etnyre & Lee, 1988; Ferber et al., 2002; Osternig et al., 1990; Osternig et al., 1987). The majority of studies analyzed have focused on the evaluation of the hamstring and soleus muscles (Condon and Hutton 1987; Etnyre et al. 1986; Ferber et al. 2002; Guissard et al. 2001; Handel et al.1997; Mc Hugh et al. 1998; Osternig et al. 1987; Osternig et al. 1990) , and as a result, information available on this topic is very limited and comes primarily from work on the lower and upper limbs. However, their effectiveness in treating muscles of mastication has not been proven.

The purposes of this study were 1) To evaluate the effectiveness of the agonist contract – antagonist relax technique (AC) in relaxation of the masseter, anterior temporalis and cervical muscles (the upper trapezius, and splenius capitis) through electromyographic activity assessment, and 2) To demonstrate that the AC technique will

lead to greater relaxation than the contract- relax technique (CR) when exercising the masticatory muscles (masseter and anterior temporalis).

In order to answer these questions, this section will be discussed in the following sections: 1) The effectiveness of the AC technique in relaxation of the masticatory muscles and the cervical muscles 2) The effectiveness of both, the AC and the CR techniques in relaxation of the masticatory muscles 3) strengths and weakness of this study.

5.1 EFFECTIVENESS OF THE AC TECHNIQUE IN RELAXATION OF MASTICATORY MUSCLES AND CERVICAL MUSCLES

The first hypothesis of this research was: the AC technique (when it is applied to the supra- and infrahyoid muscles) would cause a decrease in electromyographic activity in the masseter, anterior temporalis, upper trapezius, and splenius capitis. This theory is based on the Sherringtonian principle which stated that during a voluntary contraction the activity of the antagonist muscle is usually depressed concomitant with the agonist contraction. This is due to an active inhibition of the antagonist motoneurons by pathways that are organized to evoke inhibition of the antagonist (Crone & Nielsen, 1994).

The results obtained in the present study did not confirm the hypothesis that the AC technique would decrease the activity in the masticatory muscles as well as the cervical muscles through the reciprocal inhibition mechanism. Instead, the AC technique caused a significant increased activity when comparing before, during and after the AC technique ($p < 0.05$, Table 4-51 and Figure 25) for all muscles. During and after the

application of the AC technique, the normalized activity of the masticatory muscles as well as the cervical muscles significantly increased compared with before the application the AC technique. These results are in agreement with those results obtained by Ferber et al., (2002), Moore & Hutton (1980); Osternig et al., (1990), and Osternig et al., (1987) who reported that Agonist Contract-Relax condition (ACR), a modified technique with similar principles to the AC technique, produced 3-6% greater knee extension range of motion values than the CR and the stretch –relax (SR) techniques, but the normalized EMG was increased 71% - 155% compared with the CR and the SR. Moreover, Osternig et al. (1990) found similar findings when analyzing the effects of the ACR technique. They found that even if the agonist –contract-relax technique (ACR) improved the range of motion of the knee, the activity of the hamstring was increased 89 -109% when comparing with the CR (contract-relax) and the stretch-relax (SR) techniques respectively. Later, Ferber et al. (2002) confirmed these results in older adults. Additionally, Moore and Hutton (1980) obtained controversial results showing different patterns of EMG (some subjects showed decreased EMG activity with CR and AC compared with SS) when analyzing the SS, the CR and the AC techniques. Nevertheless, the more common pattern found by them was that the AC technique caused greater EMG activity in hamstring muscles than the SS or the CR technique. It was found that the CR and the CRAC technique produced median values of 300% and 710% more EMG hamstring activity respectively, over static stretch EMG levels. However, the CRAC technique produced the greatest extent of hip flexion, followed by the SS method, and lastly by the CR stretch (136.6°, 133.7°, and 132.8° respectively).

Condon and Hutton (1987) also found that PNF procedure using the AC technique was ineffective in minimizing EMG activity, however, the H reflex was smaller during the AC and the Hold –relax-agonist contraction (HR –AC) compared with the SS and the Hold relax (HR) techniques, which may reflect lower excitability of the motoneurons. These findings are in accord with those found by Etnyre & Abraham (1986), who reported a marked suppression of the motor pool excitability through a decrease of the H reflex in soleus muscle during early post contraction latencies of antagonist muscles during the AC technique, confirming the finding of Condon and Hutton (1987).

The conclusion stated by Condon and Hutton (1987) was that the reciprocal inhibition phenomenon may have occurred during the antagonist contraction but was masked by other neurogenic excitatory impulses to the antagonist motoneuron pool. The final result was increased muscle tension and activity when muscles were stretched. This hypothesis could also explain the results obtained in the present study.

Guissard et al (1988) also found that the H reflex was almost completely inhibited during the first 5 seconds of application of the AC and the CR stretching technique but not in the SS. This inhibition of the H response did not change significantly during the 25 seconds of lengthening in these procedures (the AC and the CR). In the present study, the EMG activity of all muscles was studied for 10 seconds during and 10 seconds after the application of the AC technique, but it was found that, neither during nor after, the normalized EMG activity of the masticatory muscles and cervical muscles was decreased. Therefore, the inhibition found by these authors (through H reflex evaluation), was not found through EMG study in the present project. Thus, it could have been possible that as with previous research , reciprocal inhibition might have occurred during the contraction

of the suprahyoid and infrahyoid muscles , but was masked by other neural processes, such as a phenomenon stated by Hultborn (1976). He found that quadriceps motoneurons inhibited the associated reciprocal interneurons of the hamstrings muscles (Ia) through a Renshaw interneuron. As a result, Ia activity to the hamstring was inhibited as the quadriceps became increasingly active. Consequently, hamstrings were more active when quadriceps was contracting. Similarly, in the present study the activity of the masticatory muscles and the cervical muscles was increased when suprahyoid and infrahyoid muscles were contracting.

Another explanation of the results obtained was that the measurement of the EMG activity during and after the application of the AC technique was not sensitive enough to demonstrate the reciprocal inhibition since the EMG activity reflects only the motor unit action potentials active during the measurement period and under the pick up surfaces (electrodes), but does not show the reciprocal inhibition mechanism as when studying the H reflex.

Additionally, reciprocal inhibition in lower extremities has been proved by Crone and Nielsen (1994); Shindo et al. (1984); Kasai and Komiyama (1991); Leonard et al. (1999) and Sinkjaer et al. (1995) through the measurement of the H reflex behavior. For example, Crone and Nielsen (1994) evaluated 74 healthy subjects and short latency reciprocal inhibition was found in the majority of the subjects (60 subjects) when analyzing the H reflex in soleus muscle. The average amount of inhibition for 74 subjects was 15%. However, the amount of reciprocal inhibition varied considerably between individuals. According to these authors, several factors may determine the amount of inhibition and explain the failure to demonstrate the inhibition in some subjects. They

stated, for example, in soleus muscle, that the activation of the peroneal muscles together with tibialis anterior can cause excitatory information in soleus muscles, which may have masked the reciprocal inhibition. Additionally, Condon and Hutton (1987) reported that maximal contractions of the antagonist muscles may trigger co-contraction of the agonist muscles. In the present study, submaximal contractions (25% of MVC) of the suprahyoid muscles were used as stated by Leonard et al. (1999). This was used since submaximal contractions of the antagonist muscles increase the amount of inhibition and subsequent muscular relaxation. Submaximal contractions also avoid the subsequent co-contraction of the agonist muscles, improving the reciprocal inhibition. However, because of the nature of the movement and the complexity of the craniomandibular system, it may be possible that the contraction of the suprahyoid muscles caused a co-contraction of the masseter and the anterior temporalis. This may have occurred to control the jaw movement and thus the activity was increased instead.

According to Carter et al. (2000), depending on the size of the muscle, it could be possible that larger muscles have more spindles per unit than small muscles. The more spindles they have, the more reciprocal inhibition, since more receptors can send a larger information through Ia afferents to the spinal cord and consequently to cause a greater inhibition on the antagonist muscles. Studies in rats have demonstrated that jaw closing muscles contain muscles spindles (Maier, 1979; Rokx, Van Willigen, and Jensen, 1984; Scutter and Turker, 2001). Additionally studies in humans have established that temporalis muscle displayed approximately 342 spindles, the masseter muscle 114, the medial pterygoid 59, and the lateral pterygoid muscle contained 6 muscles spindles (Kubota, and Masegi, 1977). However, the amount of spindles of the jaw openers has

been discussed. According to some studies in rats (Maier, 1979; Rokx et al., 1984), the amount of spindles in suprahyoid muscles is not homogenously distributed. For example, the geniohyoid and the mylohyoid muscles presented spindles, but the anterior and the posterior digastric and the stylohyoid did not show any spindle. Nevertheless, the infrahyoid muscles such as the sternohyoid, the omohyoid, and the sternothyroid presented spindles (Rokx et al 1984). These findings could explain the fact that maybe the reciprocal inhibition was not evidenced in this current study since the few spindles located in the jaw openers did not stimulate the relaxation in masticatory muscles. Nevertheless, these conclusions are based mainly on animal studies with small sample of muscles. The study of muscular receptors in human masticatory muscles is still limited because the procedures are invasive. More research is necessary in this area in order to clarify their role in the control movement of the jaw.

It would have been useful to design a study of the reflex activity of the muscles analyzed in this study (H reflex) to determine the excitability of the motoneurons when applying the AC technique. It is known that the H reflex is caused by activation of the Ia afferents fibers with monosynaptic projections to alpha-motoneurons. The stimulation applied to the peripheral nerve, which innervates the antagonist muscle, activates the Ia afferent fibers that project to interneurons. These in turn, form inhibitory synapses with the antagonist alpha motoneurons. The size of the H reflex is an indicator of the amount of reciprocal inhibition that has been evoked by the stimulation. Nevertheless, the resources (invasive method and expensive) and the objectives of this research did not cover this issue. Future investigations could study the effect of the PNF techniques in masticatory muscles and cervical muscles through evaluation of the H reflex.

Another important event to note is that even if the increase in normalized EMG was statistically significant for all muscles, masticatory muscles increased their activity in a lower proportion than the cervical muscles being practically clinically not significant (the masseter [4.167, 5.300, 4.493 normalized EMG values as percentages of the maximum reference contraction (in volts)] and the anterior temporalis [4.310, 5.240, 4.493 normalized EMG values as percentages of the maximum reference contraction (in volts)]) (see Table 4-54). For example, for the masseter muscle, the increase from before to during was 1.133 %, and from during to after, there was a decrease of 0.807%. Even if these values were statistical significant, they were not as great as the increase obtained in the cervical muscles. For example, the normalized EMG of the upper trapezius from before to during was 11.994%, and from during to after was 10.905%. The increase of the activity of the masticatory and the cervical muscles could be explained by the fact that when the AC technique was applied to the suprahyoid muscles, activity in the antagonist muscles could have been generated in order to control the movement in the jaw. Also, the increase of the cervical muscles activity could be explained because the contraction of suprahyoid and infrahyoid muscles generated a moment of cervical flexion. Thus, cervical muscles, even thought they are antagonist for this movement, acted as controllers of the flexor movement, acting more than passive antagonists, trying to make the movement stable at the level of the jaw. This was also noticed during the experiment. When subjects exerted the maximal contraction of masticatory muscles, they tended to increase the activity of the cervical muscles to make the cervical spine stable for the jaw movement. This finding could be supported only theorically, as stated by Rocabado (1979), Kapandji (1990) and Makofsky (1989). The craniomandibular system is a

complex group of structures that work together. The movement of one structure influences the position and functioning of the other structures. Some studies have tried to support this statement. For example, Funakoshi, Fujita, & Takehana (1975), Koho et al. (2001a), Koho et al. (2001b) Yamabe, Yamashita & Fuji (1999), and Yamada, Ogawa, & Koyano (1999) have reported that there is a relationship between the movements of the head and jaw position and muscular activity of masticatory muscles. However, these reports are based on small populations (pilot studies) and have weak external validity which makes the explanation suspect about this behavior. However, because there is not an absolute answer and there is not a strong conclusion that cervical spine and structures can not be related to the jaw and masticatory muscles function, is still a possible explanation, but with weak support. Therefore, more research is necessary to make any conclusions about this relationship and its clinical implications.

In summary, the AC technique did not decrease the activity of the masticatory muscles or the cervical muscles. The mechanism of reciprocal inhibition causing muscular relaxation when applied to the antagonist muscle is not supported by this study. This mechanism might have occurred, as stated previously and it could have been masked by complex neural interactions. However, the study of these interactions escaped the methodology used by this research. More research looking for the possible mechanisms of PNF techniques and the positive responses obtained in flexibility and range of motion of the patients is necessary.

5.2 EFFECTIVENESS OF BOTH THE AC AND THE CR TECHNIQUES IN RELAXATION OF MASTICATORY MUSCLES

The second hypothesis of this study was that the AC technique would cause greater relaxation of the masticatory muscles (the masseter, anterior temporalis), causing a greater decrease in EMG activity compared with the CR technique after each of the 2 activities. A two way ANOVA with repeated measures analysis demonstrated that there were no significant differences in normalized EMG activity (before- after) between the masticatory muscles for the AC and the CR techniques. There were no significant differences between each technique (the AC and the CR) and between the muscles (the masseter and the anterior temporalis)

However, when one analyzes the mean differences of each technique, the AC technique caused a smaller increase in the activity of the masticatory muscles (not significant) than the CR technique. However, both techniques did increase the activity of masticatory muscles, which means that both techniques did not cause relaxation of the masticatory muscles. Instead they caused an increase of the EMG activity. Therefore, the second hypothesis was also rejected.

The effectiveness of AC technique was discussed previously. Therefore, the following discussion will be focused on the CR technique.

In studies that analyzed the effectiveness of the AC and the CR together using the EMG activity of muscles, the AC technique always increased the activity of the muscles in a larger magnitude when comparing with the CR and the SS technique (Condon and Hutton, 1987; Etnyre et al., 1986; Ferber et al., 2002; Osternig et al., 1987; Osternig et al., 1990). These findings were not supported by the results obtained in the present study.

The increase in the EMG activity caused by the AC and the CR technique was not significantly different, thus both techniques caused an increase in the normalized EMG activity of masticatory muscles. However, the AC technique caused a smaller increase in the EMG activity of the analyzed muscles than the CR technique. This could be explained because of the methodology used, and the group of muscles used, which were not analyzed in the previous studies, making the comparison more difficult.

Nevertheless, as discussed previously, based on studies performed by Condon and Hutton (1987) and Etnyre and Abraham (1986), the H reflex in the AC technique showed a larger marked suppression as compared with the CR and the SS technique which showed that the AC technique was more effective in causing muscular inhibition or decrease the motoneurons excitability than the CR technique. Thus, this greater suppression of the AC compared with the CR technique might be an explanation for the small difference in the results found by this study.

Conversely, in a study performed by Guissard, Duchateau, and Hainaut (1988) using 28 subjects, both the AC and the CR technique depressed the H reflex .This depression lasted at least 25 seconds during the stretching procedure, showing no differences in effectiveness, which is in accord with the results obtained by this research In the present study, both techniques caused the same effect in the masticatory muscles (an increased muscular activity). However, the results obtained in the current research are not in agreement with those of Guissard et al. (1988) as that they caused an increase in the normalized EMG activity of the masticatory muscles instead of causing muscular relaxation.

According to Moore and Hutton (1980), the increase of EMG activity in the CR technique could be explained by a static contraction promoting facilitation of the same muscle. In addition, Ib activity has been shown to be momentarily depressed following tetanic contractions of muscle on stretch, contributing to increase the activity of the muscles after their contraction. Even so, the current study did not used tetanic contractions, which makes this explanation of increasing the EMG activity of the masticatory muscles not very likely to contribute to greater EMG activity during the CR technique.

Etnyre, Kinugasa & Abraham (1990) also studied the motor pool excitability, as measured by the Hoffmann reflex responses during the first few seconds after a maximum isometric contraction. They found that the most profound inhibitory influence was observed during the first 200 milliseconds following the end of contraction. Nonetheless, the H reflex amplitudes for more than 200 milliseconds following the end of contraction were not as greatly suppressed as those immediately following the end of the contraction. Therefore, after a maximum contraction, there is a suppression of the motoneurons that last not longer than 1800 milliseconds. These results are in agreement with those obtained by Moore and Kukulka (1991) since they found that H reflex depression began immediately (0.05 seconds) after contractile EMG activity declined. The duration of the phase of maximal reflex inhibition, however, was very brief. The period of maximal inhibition obtained by these authors lasted from 0.1 to 1 second postcontraction, with recovery to 70% of control reflex amplitudes (baseline) within 5 seconds postcontraction, and 90% of control amplitudes at 10.05 seconds postcontraction. The immediate effect of post contraction relaxation as stated by Etnyre et al (1990) is a

profound inhibition of the homonymous motor pool from the intrafusal-fibers and other spinal influences. This immediate post-contraction inhibition may be attributed to the inhibitory influences of tendon organs through Ib afferents or spindle secondaries through type II afferents. However, there is only limited evidence of the existence of Golgi tendon organs in human or animal jaw muscles. According to Matthews (Matthews, 1975), tendon organs have been identified histologically in the masseter and temporalis of the cat. Nevertheless, the study of these receptors in human has not been performed. Also, the functional connections of these afferents in masticatory muscles are still unknown (Matthews, 1975; Turker, 2002). Thus, the role of these structures in causing autogenic inhibition in masticatory muscles is unidentified.

Tension from isometric contraction has been shown to provide a very low stimulus threshold for the Golgi tendon organs and to result in an inhibitory influence from the Ib afferent through an interneurons on the motor pool of the homonymous muscle. However, is this inhibition clinically meaningful if the time is as short as 200 milliseconds (msec) until 5 seconds? Is this time enough to apply a stretch procedure or use this technique as a procedure of muscular relaxation? This idea was also stated by Gollhofer et al. (1998) who found that mechanical and electrical stimulation of the triceps surae muscles produced marked reductions in reflex excitability. However, the very fast recovery (< 400ms) of the excitability of the motoneurons after isometric precontraction contradicts the use for more efficient stretching of the musculotendinous system after the use of the CR technique.

On the other hand, H reflex was not investigated by this current research; therefore the conclusions obtained by those authors are not comparable with the results

obtained by the present study. The study of the effectiveness of these techniques in range of motion of the TMJ and also the H reflex responses could be a possible origin of future investigations.

In summary, the AC technique was not more effective than CR in decreasing the EMG activity of masticatory muscles. Both techniques were unable to cause muscular relaxation. Therefore, based on the results of this research, the use of these techniques as a method to cause muscular activity reduction is not supported.

5.3 STRENGTHS AND WEAKNESSES OF THIS STUDY

5.3.1 STRENGTHS

This study was the first study of the PNF effectiveness in masticatory muscles. This study has not been done previously and it is the beginning for more research in this area. Even if the results were not favorable to demonstrate that PNF techniques decrease the activity of the muscles, they increase the interest of studying the mechanisms of action of these techniques.

In this study, all subjects were healthy and between 18-35 years of age. They were evaluated previously by a dentist and a physiotherapist to determine if they met all the inclusion /exclusion criteria for this study. All the subjects were absolutely free of symptoms, with normal occlusion, normal posture and teeth with stable restorations. This made the sample homogenous and easier for making comparisons. Moreover, all data obtained were normalized with the maximal referential contraction for each muscle analyzed making the EMG activity comparable.

The sample size used was large enough to obtain good power (0.80). Most of the experiences described previously did not report the power used, using small sample sizes which makes the external validity of those results questionable.

5.3.2. WEAKNESSES

The results obtained in this research are only applicable for the group of subjects used and protocol used and can not be applicable to patients, since the behavior of the muscles under pathological conditions could be different.

All the procedures for this experiment were performed in the supine position. This makes the results obtained applicable only to the supine position since any other position, the biomechanical behavior of the muscles and the synergies are different.

The maximal voluntary contraction of the masticatory muscles and the cervical muscles was performed in supine position to allow the normalization process in the same position as the experiment. However, the level of maximal contraction obtained for cervical muscles during the testing was low, so that, the EMG activity of the cervical muscles, when contracting submaximally, was very close to the maximum level. Still, the change occurring at different times for these muscles was demonstrated.

Electromyography is a technique that depends on many factors to provide information about the muscle and its nerve supply, and of course, has limitations in the interpretation of the end results. The information must be interpreted very carefully according to the limitations of this technique. Technical considerations such as the electrodes placement, preparation of the skin, amplifier location, and use of filters are very important when using EMG. Therefore, possible contamination of the signals with noise is always an issue and should be considered in the interpretation of the results. In

the present study, the electrodes used were passive which made careful preparation of the skin and the electrode placement more important. Moreover, the leads were placed as straight as possible to eliminate kicking, to decrease the noise contamination. In addition, the signals were filtered to decrease extraneous noise affecting the EMG information. All of these considerations were applied in order to make the EMG signals contaminated as little as possible and the analysis of the results more reliable.

It would have been interesting to measure the ROM reached after each technique in order to compare with the studies that described an increase flexibility expressed as larger ROM of the joint when using PNF techniques (Godges, Mattson-Bell, Thorpe, & Shah, 2003; Nelson, William, & Cornelius, 1991; Spernoga, Uhl, Arnold, bruce, & Gansneder, 2001) and also with those studies that found increased ROM although the EMG activity was increased (Ferber et al., 2002, Moore & Hutton 1980;Osternig et al., 1990, and Osternig et al., 1987). However, it was not an objective of this research since subjects had normal ROM which makes it difficult to increase the ROM further. The measurement of ROM could be more useful in patients with impairment in the motion of the jaw. Future research could study the effectiveness of PNF technique in patients.

6. CHAPTER 6: SUMMARY AND CONCLUSIONS

6.1 SUMMARY AND CONCLUSIONS

The purposes of this study were 1) To evaluate the effectiveness of the agonist contract – antagonist relax technique (AC) in relaxation of the masseter, anterior temporalis and cervical muscles (the upper trapezius, and splenius capitis) through electromyographic activity assessment, and 2) To demonstrate that the AC technique will lead to greater relaxation than the contract- relax technique (CR) when exercising the masticatory muscles (masseter and anterior temporalis).

Based on the results of this study, the following conclusions can be stated:

1. The AC technique caused a different normalized EMG activity for all muscles at different times. However, the AC technique did not cause a decrease in the EMG activity either of the masticatory muscles or of the cervical muscles. Conversely, the AC technique caused an increase in the activity of all muscles during the application of this technique
2. PNF techniques (the AC and the CR techniques) did not cause relaxation of the masticatory muscles. Nevertheless, the AC technique caused less increase (not significant) of the EMG activity of masticator muscles than the CR technique.
3. The behavior of all muscles was similar in the way that all the muscles increased their activity when the AC technique was applied, following a pattern of synergy in order to stabilize the craniomandibular system.

4. The physiological mechanisms of PNF techniques, which stated that they act through reciprocal inhibition and autogenic inhibition causing muscular relaxation, are not supported by this study. These mechanisms might have occurred, as stated previously and they could have been masked by complex neural interactions. However, the study of these interactions escaped the methodology used by this research. More research looking for the possible mechanisms of PNF techniques and the positive responses obtained in flexibility and range of motion of the patients is necessary.

6.2 CLINICAL RELEVANCY:

Generally, physiotherapists use many techniques to treat pathological conditions without having clear knowledge about these procedures and their effects. PNF techniques have been used in clinical practice to improve range of motion and to increase muscular relaxation. However, the causes of these effects are not clear. Muscle alterations are a common problem in TMD. They may be solved by a multidisciplinary team including physiotherapists, who must apply their knowledge in this area to help to their patients to improve muscular problems.

This study showed that the AC and the CR techniques were not effective in causing muscular relaxation in masticatory muscles. Neither the AC nor the CR showed a decrease in the normalized EMG activity. Instead, the AC technique caused an increase in the EMG activity of masticatory muscles as well as the cervical muscles (the AC technique) and the CR increased the normalized activity of the masseter and anterior temporalis. Thus, PNF techniques did not cause a decrease in the EMG activity of the

analyzed muscles. Even so, based on the methodology used by this research, it cannot be stated that they are not effective in increasing the flexibility of the muscles, improving the ROM of the joints, as shown by other studies.

This research focused only in normal subjects in a very standardized situation. Future studies will be necessary to cover pathological conditions affecting patients or other positions, which could allow for greater expansion of this topic and improve the knowledge in this area, using different methodologies in order to discover the possible mechanisms involved in the effectiveness of the PNF techniques.

6.3 SUGGESTIONS FOR FUTURE INVESTIGATIONS

Some directions for future investigations would be:

1. Investigate the effectiveness of the PNF techniques in a group of patients with TMD, with restricted mobility of the jaw, and also in a group of patients with increased muscular tension.

2. Use the range of motion of the TMJ as an outcome, to test the effectiveness of PNF techniques through the evaluation of the flexibility of the muscles.

3. Study the H reflex in the masticatory muscles to determine if there was inhibition of the activity of the masticatory muscles when PNF techniques are applied.

4. Investigate the application of the AC and the CR techniques in different body positions (i.e. supine, seated) in order to determine if there is a difference in the position used when applying these techniques.

5. Investigate the effectiveness of the AC and the CR techniques using different contraction times (i.e. 5, 10, 30 seconds) in order to see what time is better to cause a decrease in EMG activity of the muscles.

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Appendix 1

Information letter to subjects

UNIVERSITY OF ALBERTA

Title of the research project:
"Electromyography assessment of the activity of the masticatory and cervical muscles using the agonist contract – antagonist relax technique (AC) [Proprioceptive neuromuscular facilitation]"

Researcher:

Dr. D. Magee, Professor in the Department of Physical Therapy, Faculty of Rehabilitation Medicine at the University of Alberta.
Susan Armijo, Master of Science student at the University of Alberta.

Purpose/ Background:

Many people have muscle pain in their jaw. This pain prompts them to visit their doctor for help. Many professionals treat muscle disorders. Physiotherapists try to reduce pain and tension in the muscles. They use things such as massage, heat and exercises. We want to look at muscular relaxation techniques in this study. These relaxation techniques are based on the principle that when you contract a muscle, the opposite muscle decreases its activity, and also when you contract maximally a muscle, after its contraction, a relaxation occurs. We want to know if these techniques can be used for muscles in the neck and jaw. Your participation will help us understand these techniques.

Procedure:

To be included in this study, you will have to meet the inclusion criteria which will involve having a normal jaw and cervical spine as evaluated by a physiotherapist and your teeth in a good condition as evaluated by a dentist. If you meet the inclusion criteria and you are agree to participate, you will be asked your age and occupation. Your height and weight will be also measured.

Your skin on your cheeks and neck will be cleaned with alcohol. Then, electrodes will be applied to your neck, jaw, and the upper part of your chest with adhesive patches. The electrodes will measure activity of your muscles. You will not feel anything through the electrodes.

You will then be asked to warm up the jaw and neck muscles by moving your head in all directions and opening and closing the jaw before the test. Straps will then be put over your chest to maintain your position as you lie on a bed for testing. Also, straps will be put around your head for support. These straps are connected to a device that measures the strength of your neck muscles.

Appendix 3

Sample size calculations (Cohen, J. 1977)

The sample size calculation was base on ANOVA procedure considering:

- $\alpha = 0.05$
- $\beta = 0.20$
- Power= 0.99
- Size effect = 0.25

Formula: $nc = \frac{(n-1)(u+1)}{\text{Number of Cells (total)}} + 1$

Sample size for first hypothesis : Number of Cells

EMG activity of the muscles (expressed in % related to the MVRC) **AC technique** **Time**			
Muscles	Before AC	During AC	After AC
Right Trapezius			
Left Trapezius			
Right Splenius Capitis			
Left Splenius Capitis			
Right Masseter			
Left Masseter			
Right Ant temporalis			
Left Ant temporalis			
Number of cells	**8**	**8** **8**	**= 24**

n= table value (from table 8.4.5 Cohen J. 1977, 386: "Sample size table: n to detect f by F test at $\alpha = 0.05$ for u= 14)

n= 38 (table value)

u= (rows – 1) x (columns-1)

(8-1) x (3-1) = 14

u= 14

Applying formula:

$nc = \frac{(38-1)(14+1)}{24} + 1$

$nc = \frac{37 \times 15}{24} + 1 = 23.1 + 1 = 24.1$

nc= 24.1= 25 subjects per cell

Sample size second hypothesis: Number of cells

Time			
Muscles	before	After	techniques
Right Masseter			AC technique
Left Masseter			
Right Ant temporalis			
Left Ant temporalis			
Right Masseter			CR technique
Left Masseter			
Right Ant temporalis			
Left Ant temporalis			

8 8 = 16

- Formula: $nc = \frac{(n-1)(u+1)}{\text{Number of Cells (total)}} + 1$

- u= (rows – 1) x (columns-1) =
- u= (8-1) x (2-1)

u= 7*1= 7 (looking for table) n = 55

- applying formula : **nc= (n-1) (u +1) +1**

Number of Cells (total)

- nc= (55-1) (7+1) + 1

  16

- nc = 54 x 8 +1 = 27+1 = 28 subjects per cell

  16

Therefore, a minimum of 25 people per cell are needed for the first design and 28 subjects are needed for the second design. To increase the reliability and power of the measurements 30 subjects will be evaluated for each condition.

Appendix 4

Evaluation test for the Subjects to Determine Eligibility for This Study

1. DEMOGRAPHIC DATA

I.D	
Age	
Weight	
height	
date	
Occupation	

2.POSTURAL ASSESSMENT (in cms.)

Malar sternal relation (maximum 6cm)+	
Apex cervical spine -plome (maximum 12 cm)	

3.RANGE OF MOTION CERVICAL SPINE

	Normal(see Magee,2002)	Abnormal
Flexion		
Extension		
Rotation left		
Rotation right		
Side flexion left		
Side flexion right		
Pain cervical spine		

+(Rocabado , 1979)

4.EVALUATION TMJ

	Normal	Abnormal
Opening 4 cm minimum		
Closing		
Laterality Right 0.7 cm minimum*		
Laterality left 0.7 cm minimum*		
Protrusive 0.6 cm minimum*		
Clicking	without pain	painful
Observations:		
Exclusion criteria :		
Clinical pathology in Temporomandibular joint (TMJ)		
Clinical pathology in cervical spine (CS)		
Pain in TMJ		
Pain CS		
Neurological problems		
Medication (specify)		
Dentist Requirements • 4 first molar in mouth • Overjet and overbite ranging from 2 to 4 mm. • No anterior or lateral crossbite. • No root canal treatment in the first molar • Acceptable condition of restorations(stables)		

* (Normal values according to Sturdivan, J and Fricton, J, 1991)

OBSERVATIONS:.....

.....

Appendix 5

Advertising for Recruiting Subjects

Are you healthy? Do you have no problems in your neck or jaw? Are you between 20 and 35 years old?

We invite you to participate in our study. We are looking at two muscular relaxation techniques for the neck and jaw. This study will help people who suffer muscular pain in this area. The entire procedure would take only one and a half hours. If you wish participate call 492-4824, or write an e-mail to Susan Armijo (sla4@ualberta.ca) . You can also go to Corbett Hall and register in room 1- 39.

Thank you in advance.

Appendix 6

EMG Equipment Characteristics

Name: EMG 100C

Specifications:

Gain: 500, 1000, 2000, 5000

Output range: ± 10 V (analog)

Frequency response

Low pass filter: 500 Hz, 5000 Hz

High pass filter: 1.0 Hz, 10 Hz, 100 Hz

Notch filter: 50 dB rejection @ 50 / 60 Hz

Noise voltage: 0.2 μV rms – (10-500 Hz)

Signal Source: Electrodes (3 electrodes leads required)

Z input

Differential: 2 M

Common Mode: 1000 M

CMRR: 110 dB min (50-60 Hz)

CMIV referenced to amplifier ground: ± 10V

Mains ground: ±1500 VDC

Input Voltage range:

Gain	Vin (mV)
500	±20
1000	± 10
2000	± 5
5000	± 2

Weight: 350 Grams, Dimensions: 4cm (wide) x 11 cm (deep) x 19 cm (high).

Transducer Amplifier Module

DA 100C Differential Amplifier Module

Figure: DA 100C differential Amplifier Module

The differential amplifier module (DA100c) is a general purpose, single channel, differential amplifier. The DA100C gas one differential input linear amplifier with adjustable offset and gain. The DA100c is used to amplify low-level signal form a variety of sources.

DA 100C Specifications

Gain	: 50, 200, 1000, 5000
Output range	: ± 10V (analog)
Frequency Response	:
Low pass filter	: 10 Hz, 300 Hz, and 5000Hz
High pass filter	: DC, 0.05 Hz
Input Voltage	: ± 200mV (protected)
Noise Voltage	: 0.11 μV rms – (0.05-10Hz)
Temperature Drift	: 0.3μV/°C
Z (Differential Input)	: 2M
CMRR	: 90 dB min
CMIV-references to Amplifier ground	: ±10V
Mains ground	: ± 1500VDC
Voltage reference	: -10 to +10V infinitely adjustable @ 20 ma (max) (factory preset to 2 volts excitation)
Signal of source	: variety of sources
Input voltage range	: Gain / Vin (mV)
	50 / ± 200
	200 / ± 50
	1000 / ± 10
	5000 / ± 2
Weight	: 350 grams
Dimensions	: 4 cm (wide) x 11 cm (deep) x 19 cm (high)

EL 503 Disposable Electrodes

The EL 503 series snap electrodes are designed for one use only. Each peel-and-stick disposable electrode is pre-gelled and requires no additional electrodes gel or adhesive.

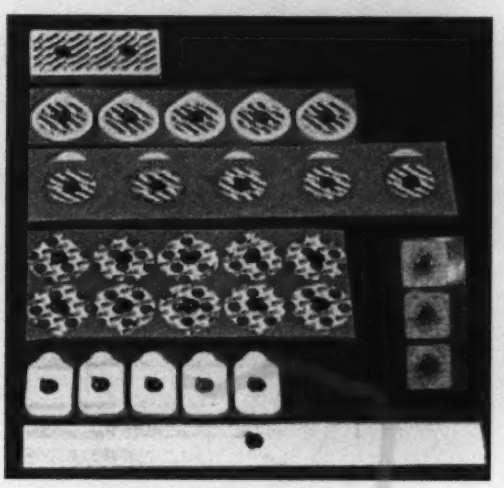


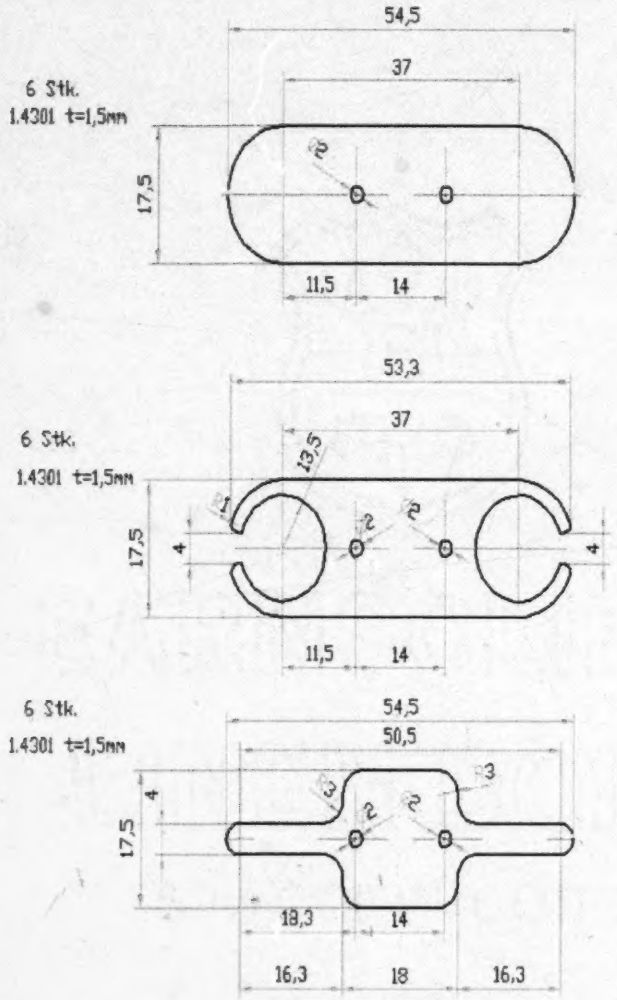
Figure: Disposable Electrodes

EL 503 Specifications:

Type	: Disposable Ag-AgCl
Fastener	: Snap fastener for attachment to lead
Gel	: hypoallergenic gel
Contact area	: 10 mm (35 mm diameter)
Material	: vinyl tape
Purpose	: General purpose

Appendix 7

Bite Force Device Characteristics



Appendix 8

Load Cell Characteristics

For Bite Force

(Omega Engineer, 1995)

Name: LCK series- LCK-250

Specifications:

Signal output: 2mV/V nominal

Linearity and hysteresis: ± 0.1 % full scale

Zero Balance: ± 2%

Compensated temperature range: 60° F to 160°F

Operating temperature range: -65° to 250° F

Temperature effect: Zero O.o1% full scale /° Span o.o1% of reading /° F

Bridge resistance: 350 ohm bonded foil gage

Excitation Voltage: 5 Vdc, 7 Vdc max

Full scale deflection: 0.001 "to 0.003 "

Safe overload 150%

Construction Stainless steel

Electrical: 5 ft. four conductor cable

Weight: < 0.5 oz.

Appendix 9

Load cell Characteristics for

Cervical Muscles MVRC Evaluation

(Omega Engineer, 1995)

Name: LCCA series 250 to 20000 lbs capacity

Specifications:

Rated output: 3mV/V +- 0.0075 mV (actual output supplied with each cell)

Excitation: 10 Vdc (15 Vdc maximum)

Accuracy: 0.037 % full scale

Linearity: 0.03% FS

Hysteresis: 0.02% FS

Repeatability: 0.01% FS

Zero Balance: 1% FS

Creep in 20 min: 0.03% FS

Maximum Load: 200% FS

Construction: Nickel Plated Steel

Cable: 20' 4 –conductor shielded 22 gage wires.

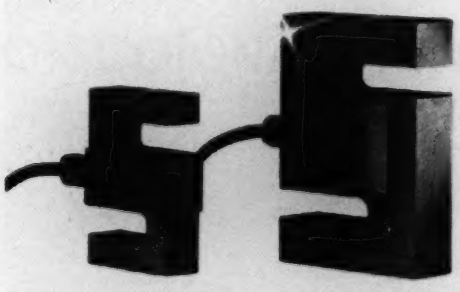


Figure: load cell to measure cervical extensor muscles force

Appendix 10

Dynamometer for

Suprahyoid Force Evaluation

(Hogan Health Industries)

http://www.hogganhealth.com/

Name: MicroFET2 Dynamometer

Specifications:

- Weight : 1lb
- Power source: 2 3.6 V ½ AA lithium batteries
  Controls: on/off, reset, threshold
- Operating temperature: (52° - °92 F (11° - 33°C)
- Humidity : 10-40% non condensing
- Accuracy : 99.5 %
- Load cell capacity : 200lbs
- Test range:
  - High threshold 0.3 lbs to 150 lbs in 1 lb increments (13N-660 Newton 0.4N increments)
  - Low Threshold : 0.8 lbs to 150 lbs in 0.1 lb increments (3.6N- 660 N 0.4 N increments)

Figure: Microfet2 manual muscle test system

Appendix 11

Data collection sheet

Patients data

I.D
Age
Weight
Height
Occupation

A: NORMALIZATION PROCEDURE

Maximal voluntary referential contraction (measured in Newtons)

Muscles	M1		M2		M3		mean
Cervical extensors							
Masticatory muscles	L	R	L	R	Mean L	Mean R	General Mean
Suprahyoid muscles	M1		M2		NA		Mean (pounds)

Muscles	Volt 1				Volt 2				Volt 3			
Cervical extensors	TL	TR	SL	SR	TL	TR	SL	SR	TL	TR	SL	SR
Cervical Extensors	MTL			MTR			MSL			MSR		
	Masticatory Muscles											
Masseter	L		R		L		R		Mean L		Mean R	
Temporalis	L		R		L		R		Mean L		Mean R	

EMG activity of the muscles (expressed in Volts)										Technique
Muscles	Before AC			During AC			After AC			AC technique
Right Trapezius										
Left Trapezius										
Right Splenius Capitis										
Left Splenius Capitis										
Right Masseter										
Left Masseter										
Right Ant temporalis										
Left Ant temporalis										
Masticatory muscles										CR technique
Right Masseter				N/A						
Left Masseter				N/A						
Right Ant temporalis				N/A						
Left Ant temporalis				N/A						

EMG activity of the muscles (expressed in percentage of the MVRC)										Technique
Muscles	Before AC			During AC			After AC			AC technique
Right Trapezius										
Left Trapezius										
Right Splenius Capitis										
Left Splenius Capitis										
Right Masseter										
Left Masseter										
Right Ant temporalis										
Left Ant temporalis										
Masticatory muscles										CR technique
Right Masseter				N/A						
Left Masseter				N/A						
Right Ant temporalis				N/A						
Left Ant temporalis				N/A						

Appendix 12

Reliability of EMG

EMG reliability has been studied for years. Jan et al. 1983 showed EMG reliability to be higher for submaximal voluntary isometric contractions than for MVC. On the other hand, Ebenbichler et al. (2002) showed high ICCs reflecting the reproducibility of values between sessions, which ranged between 89.5 and 99.0 for short term (2 hours) and long term (2 weeks) respectively. Koumantakis et al. (2001) concluded that the EMG measures derived from time-frequency analysis procedures were reliable and supported the use of this technique in monitoring muscle fatigue during dynamic real world tasks. Lehman GJ (2002) stated that intraclass correlation of the EMG signals of the paraspinal musculature on 3 separate days during quiet stance with 3 different normalization techniques—percent maximum voluntary contraction, percent submaximal contraction, and percent averaged submaximal contractions were repeatable with a intraclass correlation (ICC) > 0.75. These data, related to degree of repeatability and intraclass correlation coefficient (ICC) are in agreement with those of other studies performed by Lariviere et al. 2002 (ICC range 0.68-0.91) and Rainoldi et.al. 2001. (ICC > 70%).

Appendix 13

Specific Instructions for Patients During the Procedure

Thank you for agreeing to be evaluated as part of this research project. I am going to put these electrodes on your jaw and on your neck. These electrodes are sticky, but they will not cause any pain or unpleasant sensation.

You will be lying in this bed with this strap around your head. I am also going to put a strap across your chest to keep you still and to support you. You can relax while I am doing this.

Once you are in position with a strap around the back of your head. I will ask you to push backward as strong as you can, maintaining the position of the head, without moving your head up or down. You have to keep your eyes on the point in front of you and try not change the position of the head. Your arms and legs have to be relaxed and they should not be used to push backward. Your mouth should stay relaxed, without clenching or biting your teeth. You will repeat this backward movement 3 times. I am going to first say: "are you ready" and then "go". When I say "go", you will push backward as hard as you can, and then when I say "stop" you will stop pushing backwards. We will practice this movement until you feel confident doing it, and then we will do the testing with 3 repetitions, with a rest period of 3 min between each repetition.

Next, I am going to put a small device in your mouth in order to measure the force of your masticatory muscles. I am going to put it on one of your molars .You then be asked to bite over down on it as hard as you can. The instructions will be the same as mentioned previously: "are you ready ", "go "and "stop". We will practice this procedure before testing, so you are familiar with the procedure and when you are ready, we will do

the measurements. You will be asked to bite down hard 2 times with 3 min rest between each repetition.

Next, I am going to apply a resistance under your chin with a specific tool (dynamometer) that measures force. Then you have to push your jaw against the dynamometer as strong as you can. The instructions will be the same as I mentioned previously: "are you ready?", "go", and "stop". You will perform this procedure twice. Then I will train you to exert 25-30% of this force. We will practice until you understand how to do it and are comfortable doing it. When you are ready, we will then do the testing and I will register the activity of your muscles while you push against the dynamometer. The instructions will be:" are you ready?", "Go", "press very lightly"," hold", and "stop". This procedure will be repeated 3 times with 3 min rest between each repetition.

Finally, you have to bite over a piece of rubber with your front teeth as strong as you can for 5 seconds. The instructions are the same as before: "are you ready?", "go", and "stop". We will practice this procedure before testing, so you are familiar with the procedure and when you are ready, we will do the measurements. This procedure will be repeated 3 times as well with a 3 minutes rest period after each contraction.

Once this test is performed you will finished,

Thanks so much for your time and consideration.